Overcoming Barriers to the Use of Commercial Integrated Circuit Technology in Defense Systems

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Preface

Acquisition reform is central to the Defense Department's strategy for preserving the technological superiority of US forces at an affordable cost. It is the foundation for our overall strategy of placing greater reliance on the commercial sector to reduce costs, shorten acquisition time, and obtain technologically advanced defense equipment.

This report builds on current acquisition reform efforts in the critical area of semiconductor integrated circuits (ICs). Its recommendations further the Department's goal of merging commercial and military production in the IC industry by helping overcome barriers to greater use of commercial IC technology in defense systems.

I strongly support this report's recommendations and urge the acquisition community to work towards their speedy implementation.

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Table of Contents

Figures

Tables

Executive Summary

This is a summary of the Department of Defense (DoD) report *Barriers to the Use of Commercial Integrated Circuit Technology in Defense Systems*. This report addresses the following issues:

- It describes the motivation for using commercial integrated circuit (IC) technology in defense systems — commonly referred to as "commercial IC insertion."
- It places commercial IC insertion within the wider goal of current DoD acquisition reform efforts: the merging of most defense production into the commercial industrial base.
- It identifies technical and cultural barriers to achieving a more integrated industrial base for ICs.
- It recommends near-term actions for overcoming these government-imposed barriers to commercial IC insertion and industrial base integration, and thus for moving current DoD acquisition reform efforts forward.

DoD needs a long-term strategy for effectively dealing with commercial IC suppliers. Taking best advantage of commercial IC technology in defense systems will depend on complementary changes in DoD electronics development and acquisition practices. Defense systems design, procurement, production, maintenance, upgrade, and support practices must be compatible with best commercial practices, and with each other. Use of best commercial development practices, in combination with new contracting arrangements, can encourage competition throughout a system's life cycle.

In the near-term, DoD can take actions that move it toward new system development and acquisition practices. This report's recommendations focus on three main areas:

- Design Practices
- Requirements Definition Practices
- Contracting Practices

Table ES-1 summarizes the recommendations.

The need to employ commercial ICs does not diminish the importance of developing and inserting advanced, defense-unique IC technology. DoD will still benefit from using defense-unique technologies in areas where a significant technical advantage can be achieved affordably or where a distinct defense need cannot be met by adapting a commercial process or design. But for most of its needs, DoD must rely on commercial industry.

Motivation for Commercial IC Insertion

Using more commercial IC products and production facilities to meet defense needs will provide the following benefits:

- It will help the US military maintain technological superiority.

  Advanced ICs provide much of the US technological advantage enjoyed by US defense systems. However, the modern IC industry develops new products for commercial markets much faster than DoD has been able to develop, adapt, or adopt them for defense systems. As a result, defense IC technology in fielded systems has grown increasingly distant from the commercial leading edge. The US advantage is further threatened by the worldwide availability of advanced, commercial ICs. Potential adversaries can and will employ advanced, commercial ICs. *Inserting advanced ICs into fielded systems more rapidly than potential adversaries is a prerequisite for future US technological advantage.*

- It will enlarge the defense IC supplier base.

  DoD must rely on commercial industry for most of its advanced ICs. Complex ICs require many person-years of effort to design, and a single piece of modern production equipment can cost millions of dollars. Commercial manufacturers recoup these fixed costs and stay competitive by building high-volume factories. Commercial demand for ICs has grown quickly enough to absorb these high outputs, while defense IC consumption has not. Using current production philosophy, state-of-the-art facilities dedicated to low-volume, defense production runs are not economically viable. As a result, the defense supplier base is contracting.

- It will allow DoD to take advantage of the commercial IC trend toward better products and decreasing prices.

Commercial IC Insertion Builds on Existing DoD Reform Efforts

Two major acquisition reform efforts are removing barriers to better integration of defense and commercial IC production: Military Standard and Specification (Mil-Spec) reform, and acquisition streamlining. These efforts seek to eliminate unique, government-imposed contracting, technical, and accounting requirements. The goal is a simplified, commercial-style procurement system that gives priority to acquiring commercial products and processes.

DoD must continue these vital efforts. They are critical to achieving the general DoD goal of merging most defense production into the commercial industrial base. However, additional reforms are needed to address issues specific to the IC industry. This report examines issues raised but not wholly addressed by these reform efforts.

DoD Faces Technical and Cultural Barriers in Achieving a More Integrated IC Industrial Base

Mil-Spec reform has removed many technical barriers to use of commercial ICs in defense systems. At the same time, it has highlighted areas where defense application information and commercial performance data are insufficient to employ commercial ICs with confidence. Technical barriers such as these continue to restrict what DoD and its contractors buy.

Current acquisition reform efforts are centered around regulatory implementation of the Federal Acquisition Streamlining Act of 1994 (FASA) and Federal Acquisition Reform Act of 1996 (FARA). While FASA and FARA have removed important legal barriers in contracting for commercial items, their implementation is not yet complete. Cultural barriers may remain pending education of the defense acquisition workforce and changing the procurement practice of prime defense contractors. These historical contracting practices may continue to influence how, what, and from whom, DoD buys.

There is much controversy in the defense IC community concerning current acquisition reform efforts, resulting in serious debate about appropriate strategies for the future. The debate pivots on the extent to which, and the areas within which, DoD should seek to join the commercial mainstream versus working to maintain a separate IC supply and technology base. As with many debates, both sides raise valid concerns. The use of commercial ICs in any defense system will require careful consideration of the factors identified by both sides. Not all commercial ICs will operate reliably under military conditions, but neither are all defense applications equally stressing. A commercial IC suitable for a particular defense system may not be a readily available, high-volume, so-called “commercial-off-the-shelf” (COTS) product.

This Report Recommends Near-Term Actions to Overcome Government-Imposed Barriers

DoD needs a long-term strategy for effectively dealing with commercial IC suppliers. Taking best advantage of commercial IC technology in defense systems will depend on complementary changes in DoD electronics development and acquisition practices. Defense systems design, procurement, production, maintenance, upgrade, and support practices must be compatible with best commercial practices, and with each other. Use of best commercial development practices, in combination with new contracting arrangements, can encourage competition throughout a system’s life cycle.

In the near-term, DoD can take actions that move it toward new system development and acquisition practices. This report focuses on three main areas:

- ❑ Design Practices
- ❑ Requirements Definition Practices
- ❑ Contracting Practices

Overcoming Barriers in Design Practices

Barriers to the use of commercial ICs in the design stage stem from lack of appropriate technical information. In the absence of appropriate technical information, design conservatism is likely to prevail. In order to fully realize the benefits of commercial IC advances, DoD must act to overcome design conservatism. This report recommends the following improvements in technical information gathering and dissemination:

- ❑ Define new DoD IC operating environments, beyond space and non-space, to include existing commercial standards.
- ❑ Characterize commercial product performance in terms of the new operating environments.
- ❑ Coordinate IC characterization projects and dissemination of results.

In the interim, DoD needs to implement Mil-Spec reform carefully, to avoid eliminating prematurely technical specifications and standards that are beneficial to overall DoD interests.

Overcoming Barriers in Requirements Definition Practices

Most Mil-Spec ICs contain silicon die (bare chips) that are identical to those sold commercially, or are custom-made using commercial processes. Mil-Spec and commercial ICs generally have differed in two ways:

- ❑ The methods and materials used to package the IC die vary.
- ❑ The quality assurance practices applied in manufacturing are different.

In recent years, many defense products have used commercial ICs successfully. Major defense equipment and subsystem suppliers strongly support greater use of commercial ICs. With the contraction of the defense IC supplier base, a wide variety of Mil-Spec ICs is no longer available. Many ICs are available only as commercial products. Wherever feasible, defense programs should be encouraged to eliminate historical Mil-Spec requirements for packaging and quality assurance.

However, DoD must continue to specify its requirements so that the resulting product will perform its mission with acceptable quality and reliability. To further leverage commercial capabilities and to broaden the availability of commercial products that meet defense needs, DoD should reconcile Mil-Specs with best commercial practices in packaging and quality assurance. DoD can accomplish this largely through existing programs, if they are applied with care so as not to raise barriers to the use of commercial IC technology. Specifically, DoD should take the following actions:

- ❑ To better reconcile defense requirements with best commercial practices in packaging, the following efforts are recommended:
  - Establish the capabilities and limitations of commercial packaging technologies.

- Leverage commercial advances in packaging, especially in areas such as multi-chip modules.
- Continue R&D investments in advanced packaging materials and computer design tools.

❑ To better reconcile defense requirements with best commercial practices in quality assurance, the following efforts are recommended:

- Create commercial interest in the Qualified Manufacturers List (QML) program by providing technology transfer in related areas of DoD expertise.
- Enhance Standard Microcircuit Drawings (SMDs) to capture IC specifications in a form compatible with commercial standards.

Note: In certain technology areas, defense needs differ from commercial needs and cannot be met through packaging and quality assurance. Commercial ICs generally cannot operate reliably in the radiation environment following a nuclear explosion. Some DoD applications require ICs with classified designs, which must be manufactured in specially cleared facilities and protected with technologies that prevent reverse engineering. In certain defense applications, significant technical advantages can be achieved affordably by developing devices that are more advanced than mainstream commercial applications of similar devices. For example, high-performance analog ICs can confer distinct defense benefits in radar and electronic warfare applications. Likewise, custom, application-specific ICs can be essential in defense applications in which minimization of size and weight are paramount concerns.

Overcoming Barriers in Contracting Practices

The Federal Acquisition and Streamlining Act of 1994 (FASA), the Federal Acquisition Reform Act of 1996 (FARA), and their regulatory implementation have made major improvements in government contracting for commercial items. In the interim, historical cultural barriers may remain pending education of the defense acquisition workforce and changing the procurement practice of prime defense contractors. In the case of the IC industry, it is critical that DoD work to clarify the changes made in government auditing rights and intellectual property ownership in the acquisition of commercial items and for government-funded work.

In the longer term, DoD should continue exploring innovative contracting procedures that are consistent with commercial practices, facilitate competition, and encourage life-cycle cost and performance trade-offs. A wider cultural change is called for, one that rewards program managers for prudent risk-taking and managerial innovation.

Table ES-1. Summary of Barriers and Recommendations to Overcome Them

Barrier	*Effect of Barrier*	*Recommendations*
Design Practices Information about defense applications and commercial performance is often insufficient to employ commercial ICs with confidence.	**Overly conservative system designs** Uncertainty regarding new commercial technologies true performance and reliability can inhibit their use.	❑ **Define new DoD IC operating environments to include existing commercial standards.** ❑ **Characterize commercial product performance in terms of the new operating environments.** ❑ **Coordinate IC characterization projects and dissemination of results.** ❑ **Implement Mil-Spec reform carefully.**
Requirements Definition Practices: Packaging Distinct defense requirements for IC packaging.	**Unnecessary or outdated packaging requirements** can inhibit use of commercial ICs in defense systems and limit the availability of ICs that meet defense needs.	❑ **Establish the capabilities and limitations of commercial packaging technologies.** ❑ **Leverage commercial advances in packaging, especially in areas such as multi-chip modules.** ❑ **Continue R&D investments in advanced packaging materials & computer design tools.**
Requirements Definition Practices: Quality Assurance Distinct defense practices for IC quality assurance.	**Unnecessary or outdated quality assurance practices** can inhibit use of commercial ICs in defense systems and limit the availability of ICs that meet defense needs.	❑ **Create commercial interest in the Qualified Manufacturers List (QML) program by providing technology transfer in related areas of DoD expertise.** ❑ **Enhance Standard Microcircuit Drawings (SMDs) to capture IC specifications in a form compatible with commercial standards.**
Contracting Practices Historical defense acquisition practices and reforms that have yet to be implemented	**Old government contracting practices** discourage commercial companies from doing business with DoD	❑ **Clarify government auditing rights in acquisition of commercial items.** ❑ **Clarify government policy on intellectual property ownership in the acquisition of commercial items and for government-funded work.**

Section 1: Introduction

Using commercial IC products and production facilities to meet defense needs will provide the following benefits:

- ❑ It will help the US military maintain technological superiority, by helping defense programs incorporate commercial IC advances more rapidly than potential adversaries.
- ❑ It will enlarge the defense IC supplier base.
- ❑ It will allow DoD to take advantage of the commercial IC trend toward better products and decreasing prices.

Current efforts to minimize unique government specifications and acquisition regulations are clearing a path toward these goals by encouraging integration of defense and commercial IC production. DoD must continue these vital efforts. To take best advantage of the opportunities created, DoD must also devise and implement new system development and acquisition procedures that embody best commercial practices.

This report identifies technical and cultural barriers to achieving a more integrated IC industrial base. It recommends near-term actions to overcome government-imposed barriers and to move toward new system development and acquisition practices.

The Dual Use Imperative in Integrated Circuits

United States defense policy relies upon qualitatively superior military systems to achieve an advantage over potential adversaries. Advanced ICs provide much of that advantage. They are frequently the performance enablers for defense electronic subsystems, in everything from major military platforms such as front-line fighter planes and warships to the portable communication and position location systems carried by individual soldiers.

Many commercially developed ICs have defense applications; that is, they are "dual use." Both commercial laptop computers and military mobile radios benefit from ICs that provide greater functionality in a smaller size while consuming less power. However, defense technology in fielded systems has grown increasingly distant from the commercial leading edge. The modern IC industry develops new products for commercial markets much faster than DoD can develop, adapt, or adopt them for defense systems. Competitive pressures in the IC industry have driven product development cycles down to about one year. The industry introduces new generations every three or four years. It typically takes DoD ten or more years to develop or upgrade systems.

US Military Technological Advantage Will Increasingly Depend on Commercial IC Technology

Commercial ICs are available worldwide. More than half of the world's IC manufacturing capability and technical expertise in related technologies now resides overseas. The US cannot deny other countries access to these technologies. Potential adversaries can and will employ advanced, commercial ICs.[1] *Inserting advanced ICs into fielded systems more rapidly than potential adversaries is a prerequisite for future US technological advantage.*

DoD must rely on commercial industry for most of its advanced ICs. DoD demand is not large enough to economically support a defense-only, advanced IC supplier base. The fixed costs associated with developing and manufacturing state-of-the-art ICs have increased dramatically. Complex ICs require many person-years of effort to design, and a single piece of modern production equipment can cost millions of dollars. Commercial manufacturers recoup these fixed costs and stay competitive by building high-volume factories. High volume IC factories currently under construction are projected to cost over a billion dollars, but this investment is recovered over sales of hundreds of millions or even billions of parts. Commercial demand for ICs has grown quickly enough to absorb such high outputs, while defense IC consumption has not. Using current production philosophy, state-of-the-art facilities dedicated to low-volume, defense production runs are not economically viable. The cost per part would be prohibitive. As a result, the defense supplier base is contracting. While some traditional defense suppliers remain committed to serving the DoD market, other major IC producers have already dismantled their military sales and manufacturing operations.[2]

Table 1-1 illustrates what it has cost DoD to fail to leverage commercial IC improvements in the recent past. It compares technology and price trends for selected mainstream IC products over the five-year period 1987 - 1992. The table lists the older, less-complex technology first in each product category. These comparisons illustrate that (1) shipments of the less complex products declined (or increased only slightly) while shipments of the newer, more complex products increased dramatically; and (2) prices declined more rapidly for the newer products. In some cases, the average

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[1] The emerging global threat of technology is discussed in Appendix A. The specific threat posed by IC technology diffusion and its implications for DoD have been noted in several intelligence reports, including: Lt. Charles D. Ormsby, NAIC/TATA and Mr. Robert L. Robke, NAIC/GTU, *Use of Commercial-Off-The-Shelf Equipment in Military Systems -- Worldwide*, 3 July 1995 (Secret); Dennis K. Evans and Daniel W. Barr, DIA, *Microelectronics in the Pacific Rim Countries*, Document #DST-1700S-665-94, April 1994 (Secret); L. Dunn, D. Dwyer, D. Louscher, and J. Tomashoff, *Diffusion of Military Technology and Its Implications for US Defense Policy*, SAIC report # 079-04-295-0002AD, September 1990 (FOUO).

[2] In 1994, Motorola and AMD announced plans to eliminate separate organizations to supply the military. DoD will remain a customer of interest but will no longer be served by separate production and sales organizations.

price per unit in 1992 for a higher capability product was lower than the price in 1987 of the earlier generation. While DoD needs many different types of IC products beyond those listed in the table, it can still take advantage of the trend toward better products and lower prices by using commercial ICs in defense systems.

Table 1-1. Commercial IC Trend is Toward Better Products and Decreasing Prices

Product	1987 Shipments (millions)	1992 Shipments (millions)	Percent Change 87-92	Unit Price 1987	Unit Price 1992	Percent Change 87-92
Microprocessors						
4-bit & 8-bit	$365.4	$159.1	-56.4%	$3.46	$2.60	-24.8%
16-bit & 32-bit	$913.4	$2813.2	208.0%	$33.83	$4.34	-87.2%
Dynamic random access memory (DRAMs)						
< 80,000 bits	$89.4	$33.4	-62.6%	$2.94	$4.40	49.5%
> 80,000 bits	$863.6	$1279.9	48.2%	$6.80	$6.63	-2.5%
Static random access memories (SRAMs)						
< 80,000 bits	$356.8	$368.9	3.4%	$4.19	$4.07	-2.8%
> 80,000 bits	$40.2	$341.9	750.6%	$4.96	$3.30	-33.4%
Erasable programmable read-only memory (EPROMs)						
< 80,000 bits	$239.9	$158.8	-33.8%	$4.47	$4.10	-8.1%
> 80,000 bits	$344.9	$542.4	57.3%	$5.05	$1.46	-71.1%
Electrically erasable programmable read-only memory (EEPROMs)						
< 80,000 bits	$177.6	$134.8	-24.1%	$5.88	$0.93	-84.2%
> 80,000 bits	$24.4	$163.4	569.5%	$122.00	$7.26	-94.0%
Total Semiconductors						
SIC 3674	$19794.9	$21350.5	7.9%			

Dollar figures are in 1987 dollars.

Sources: "Industry Series: Electronic Components," Department of Commerce, Bureau of the Census, MC87-I-36E, 1987 and "Semiconductors, Printed Circuit Boards, and Other Electronic Components," Department of Commerce, Bureau of the Census, MA39Q, 1992 Annual Report.

Dual Use Facilities and Products are Key to DoD Strategy

Production facilities that produce both commercial and military parts, or dual use facilities, will result from the integration of military and commercial production technologies. Dual use facilities will allow the industry to meet military needs using optimized, state-of-the-art facilities. DoD leadership advocates the merging of the commercial and defense supplier bases as the primary way to achieve more rapid insertion of advanced commercial IC technology. Secretary of Defense Perry's *Acquisition Reform: A Mandate for Change* of February 24, 1994, states:

> Commercial technology advancements are outpacing DoD-sponsored efforts in the same sectors that are key underlying technologies for military superiority. DoD must have unimpeded access to commercial technologies more quickly than other countries if it is to maintain its technological superiority... [In order to] maintain its technological superiority in today's environment, [DoD must] be able to rapidly acquire commercial and other state-of-the-art products and technology, from reliable suppliers who utilize the latest manufacturing and management techniques. DoD must integrate, broaden, and maintain a national industrial base sustained primarily by commercial demand but capable of meeting DoD's needs.

This mandate was followed in February 1995 by *Dual Use Technology: A Defense Strategy for Affordable, Leading-Edge Technology*. This strategy statement, in addition to promoting the insertion of commercial technologies into defense systems, called for the following actions:

- Invest in research and development (R&D) on dual use technologies to ensure the domestic commercial technology base remains at the leading edge in areas critical to the US military.
- Transfer defense production technologies into commercial industry to leverage commercial economies of scale and scope.

However, it is important to note that the need to employ dual use, commercial ICs does not diminish the importance of developing and inserting advanced, defense-unique IC technology. DoD will still benefit from using defense-unique technologies in areas where a significant technical advantage can be achieved affordably or where a distinct defense need cannot be met by adapting a commercial process or design. But for most of its needs, DoD must rely on commercial industry.

The Current Situation

Two major reform efforts are removing barriers to the accomplishment of Dual Use Strategy goals: Military Standard and Specification (Mil-Spec) reform, and acquisition reform. These efforts seek to eliminate unique, government-imposed contracting, technical, and accounting requirements. The goal is a simplified, commercial-style procurement system that gives priority to acquiring commercial products and processes. Appendix A provides an overview of the Mil-Spec system and additional detail on reform efforts.

Additional Reforms are Needed to Address IC Issues

Mil-Spec reform has removed many technical barriers to use of commercial ICs in defense systems. At the same time, it has highlighted areas where defense application information and commercial performance data are insufficient to employ commercial ICs with confidence. Technical barriers such as these continue to restrict what DoD and its contractors buy.

Current acquisition reform efforts are centered around regulatory implementation of the Federal Acquisition Streamlining Act of 1994

(FASA) and Federal Acquisition Reform Act of 1996 (FARA). While FASA and FARA have removed important legal barriers in contracting for commercial items, their implementation is incomplete. Cultural barriers remain pending education of the defense acquisition workforce and changing procurement practice by prime defense contractors. Until that time, historical administrative practices will continue to influence how, and from whom, DoD buys.

The Right Direction for Change is Under Debate

There is much controversy in the defense IC community concerning current reform efforts, resulting in serious debate about appropriate strategies for the future. The debate pivots on the extent to which, and the areas within which, DoD should seek to join the commercial mainstream versus working to maintain a separate IC supply and technology base. The positions may be summarized as follows:

- **DoD has not moved vigorously enough toward use of commercial products and practices.** Mil-Specs are largely outdated. Informed selection of suppliers and parts, proper designs, and careful manufacturing process controls would allow nearly unlimited use of commercial ICs in defense systems. DoD can have greater confidence in the quality and reliability of commercial parts built by leading-edge manufacturers and used by thousands of customers than in Mil-Spec parts built in low-volumes. DoD should only maintain distinct suppliers in areas where a significant military advantage is achievable.
- **DoD has moved too quickly in embracing commercial ICs.** The need for military-grade electronic parts has not changed. Initial advantages in product availability and purchase cost are often offset by environmental mismatch or poor documentation, technical support, or reliability. In the interest of saving a few dollars by using commercial ICs, DoD will unacceptably increase the risk of failure in life-critical systems, reduce its efforts to achieve performance advantage through the development of military-unique ICs, and hasten the departure of Mil-Spec suppliers from the market. The loss of Mil-Spec suppliers will make it increasingly difficult and expensive to maintain existing systems. It could also eventually lead to risky foreign dependencies.

As with many debates, both sides raise valid concerns. The use of commercial ICs in any defense system will require careful consideration of the factors identified by both sides. Not all commercial ICs will operate reliably under military conditions, but neither are all defense applications equally stressing. The term "commercial" can refer to a variety of markets — for example, consumer, industrial, and automotive — with distinct manufacturing processes, technical requirements, and sales practices. For instance, commercial users of ICs such as the automobile industry maintain stringent quality control standards and testing requirements, and

they audit their IC suppliers to ensure compliance. Likewise, a commercial IC suitable for a particular defense system may not be a readily available, high-volume, so-called "commercial-off-the-shelf" (COTS) product. Special handling or adaptation of the IC's production process or design may be needed.

A Long-Term Vision for DoD IC Acquisition

DoD needs a long-term strategy for effectively dealing with commercial IC suppliers. At present, DoD largely finds itself in a reactive mode. Some programs are developing new system design practices and electronics support strategies to take advantage of commercial technology. Other programs are scrambling to cope with the loss of suppliers for specific military parts. DoD is taking steps to encourage companies to continue serving the defense market, but more needs to be done.

Taking best advantage of commercial IC technology in defense systems will depend on complementary changes in DoD electronics acquisition practices. Defense systems design, procurement, production, maintenance, upgrade, and support practices must be compatible with best commercial practices, and with each other. DoD should seek an acquisition process in which both performance and cost can be readily improved over the system life cycle, just as they are in much of the commercial electronics industry.

A single process cannot govern all defense IC procurement. Individual programs must be free to optimize for their own situation. But it would be unwise to simply abandon all DoD-wide controls and dismantle support organizations. Any new IC acquisition system must provide incentives to programs that promote wise decisions in the interest of overall national security. Managers must be provided the resources and technical support to make up-front investments that yield long-term benefits, while at the same time being held accountable for the circumstances they hand off to their successors.

Best Practices Start with Design

A defense system ideally would take advantage of IC improvements through regular, incremental upgrades to system electronics. The success of this strategy depends on forward-looking system designs that anticipate upgrades and long-term support needs. Such design flexibility requires significantly more effort and expense than simply designing to currently known technology. Designers must describe the subsystem behavior and its operating environment in great detail.

Detailed design information and behavioral descriptions reduce the cost of making a new technology compatible with existing subsystem form, fit, and function. For instance, a single, faster chip might become available to replace an entire circuit board, but the change must not compromise system performance. If detailed design information and behavioral descriptions do not exist, the upgrade will involve additional engineering effort and cost to ensure that performance is not compromised.

Detailed design information and behavioral description also make it easier for more than one company to produce a given system or subsystem. Cost reductions driven by competition can provide further payback of the up-front design investment.

DoD Must Also Remain Involved with Standards and Tool Development

Developing a new system design strategy will require more than just a change in how individual programs invest. Upward compatibility rests on an infrastructure of architectural and technical standards and on changing design, production, and testing tools. As DoD works to minimize its unique standards and to employ open system architectures, it will still want to remain involved in commercial standards development. In areas where commercial coordination is inhibited by competition, it will often be advantageous for DoD to encourage or even to lead the process. Many of today's best commercial practices began as Mil-Specs.

DoD must also remain involved in the development of new design, production, and testing tools. Developments in these areas are often windows to the future development of advanced products. DoD will not be able to look ahead effectively if it does not remain involved. It is also in DoD's interest to encourage the development of tools that facilitate affordable, low-volume production of customized ICs.

New Contracting Practices Can Support Affordability

The development of detailed, technology-independent designs and the supporting infrastructure will not by itself lead to life-cycle cost reductions or to sensible performance trade-offs. New contracting arrangements are needed to encourage effective competition throughout a system's life cycle. In the present acquisition system, one organization, usually a prime contractor, manages weapons system design and production. A different organization, usually the government, performs the support tasks such as diagnosis, repair, and spare parts procurement. This arrangement does not promote trade-offs between design, production, and maintenance costs.

The current system also does not discourage excessive "performance push." Individual program managers face incentives to optimize designs to their particular application, but not to seek long-term upgradability or cost savings. Often there are no incentives to design a system based on a commercial standard when a non-standard approach will improve initial performance, even though a system based on commercial standards can evolve more easily and be competed more effectively.

Special DoD Needs Must Be Considered

Most DoD systems will benefit from using forward-looking design, best commercial practices, and innovative contracting procedures. But it will not always be possible or sensible to seek continuous performance and cost improvement over a system's life cycle. For instance, missiles and guided munitions are operated only intermittently or are stockpiled. For such systems, maintenance and technical support over years or decades are the predominant concern. In other cases, maintenance of obsolete

hardware might be expedient to protect much larger investments in system software. Even where system upgrades have been planned, certain parts might become commercially unavailable prior to an upgrade.

The unavailability of outdated IC devices is a perpetual logistics problem for many program offices today. The problem is becoming more acute as suppliers leave the defense business. When a part looks like it will become unavailable, DoD is forced either to (1) stockpile original parts; (2) transfer technical data and tooling to a government depot or aftermarket supplier; (3) use the Generalized Emulation of Microcircuits (GEM) program, where obsolete ICs are re-engineered using generic circuitry and modern manufacturing methods; or (4) redesign some or all of a subsystem, often without the benefit of detailed design information. Maintaining and improving these options is often cumbersome and expensive, but they are likely to remain necessary well into the future. It would be imprudent to risk having an entire major system become unavailable in wartime for want of an IC.

Report Purpose, Scope, and Organization

The purpose of this report is to identify near-term steps toward integrating the IC industrial base and toward new, forward-looking defense system development and acquisition practices. The recommendations aim to accomplish the following:

- Increase the speed with which DoD realizes the benefits of using commercial ICs in defense systems.
- Enable integration of commercial and defense production.
- Keep current reform efforts moving forward in the particular case of the IC industry.
- Provide clarity and direction for DoD electronics acquisition policy.

This report identifies technical and cultural barriers raised by current military practices for design, requirements definition, and contracting. It recommends DoD activities designed to eliminate the barriers and meet the objectives above.

Topics not covered in this report include the divergence between defense and commercial technologies in specific IC areas, concerns about the long term viability of domestic semiconductor manufacturing equipment and materials industries, and the impacts of business strategies being adopted by defense suppliers in the face of industry downsizing.

Programs Need Technical Information to Define What They Need

Section 2 discusses barriers raised by lack of appropriate technical information. The Mil-Spec system permitted designers of defense systems to select standard parts out of company catalogues. The designer had confidence that the parts would operate reliably in harsh military environments or after long-term storage, and that they would be supported

for years or decades of use. In the absence of Mil-Specs, a designer must determine the environment in which the electronic system will operate, establish that a particular commercial IC will operate reliably in that environment, and plan for parts obsolescence.

The recommendations in Section 2 aim to improve technical information gathering and dissemination within DoD. Coordinated investment and training can help program offices and defense contractors determine commercial ICs that can be used confidently. It is also a step toward defense system development and acquisition practices that are compatible with continuous, incremental upgrading. In the interim, Mil-Spec Reform needs to be implemented with care. Some specifications and standards are beneficial to overall DoD interests.

DoD Can Broaden The Availability of Commercial IC Technologies That Meet Defense Needs

Improving available technical information can improve a program's technical options only if there are commercial ICs available that meet the requirements. Section 3 discusses barriers raised by technical differences between military grade and various commercial grade ICs. The primary differences have been in how silicon die (bare chips) are packaged and the quality assurance practices applied in manufacturing.

Certain R&D investments and DoD programs can help close the gap. By reconciling defense needs with commercial trends in IC packaging and quality assurance, DoD can broaden the availability of commercial ICs that can be used confidently. These efforts can also contribute to realization of long-term DoD development and acquisition goals.

Cultural Barriers Remain to Commercial IC Companies Becoming DoD Suppliers

Defining what is needed and having commercial ICs available to meet the needs will not provide the desired benefits if commercial companies are unwilling to do business with DoD. FASA and its regulatory implementation have addressed many of these issues, but cultural barriers remain. Section 4 presents an analysis of contracting practices that can discourage commercial companies from making products for the defense market. The section recommends ways to address the barriers and move DoD toward contracting procedures that are compatible with commercial practice.

Appendix A provides background on the role of DoD in the global IC market. It includes a historical perspective on the commercial IC insertion problem, describes the current situation for DoD in more detail, discusses the emerging global threat of technology, and provides an overview of Mil-Spec reform and FASA.

Appendix B describes the Mil-Spec reform implementation status in the Office of the Secretary of Defense (OSD) and in each of the Services.

Section 2: Overcoming Barriers in Design Practices

Barriers to the use of commercial ICs in the design stage stem from lack of appropriate technical information. In the absence of appropriate technical information, design conservatism is likely to prevail. In order to fully realize the benefits of commercial IC advances, DoD must act to overcome design conservatism. This report recommends the following improvements in technical information gathering and dissemination:

- ❑ Define new DoD IC operating environments, beyond space and non-space, to include existing commercial standards.
- ❑ Characterize commercial product performance in terms of the new operating environments.
- ❑ Coordinate IC characterization projects and dissemination of results.

In the interim, DoD needs to implement Mil-Spec reform carefully, to avoid eliminating prematurely technical specifications and standards that are beneficial to overall DoD interests.

Overcome Design Conservatism

System designers face significant problems in identifying a particular commercial IC to suit their application. Often, the problems are due to a lack of appropriate technical information on commercial ICs. The designers simply do not have the data to determine which commercial ICs are suitable. In such cases, designers tend to be conservative.

Design conservatism is common in hardware engineering, especially where the cost of failure is high. It represents not a reluctance to adopt a new technology, but a reaction to uncertainty regarding a new technology's true performance and reliability. For example, until recently, the Mil-Spec system discouraged use of plastic-encapsulated microcircuits (PEMs), and definitive data was lacking on the performance of PEMs in defense applications. As a result, many defense programs have only slowly accepted PEMs. This is an example of design conservatism caused by a lack of experience and data.

As designers move away from predominant use of Mil-Spec parts, they must be careful that the initial advantages in product availability and purchase cost are not lost in environmental mismatch or poor documentation, technical support, or reliability. In general, a program performs the following tasks in using commercial ICs:

- Review IC specifications, standards, handbooks, instructions, and reliability, test and field data.
- Analyze costs.
- Work out new configuration control, quality assurance, reliability, and logistics support strategies.
- Prepare novel Requests-for-Proposals.
- Evaluate bids.
- Monitor contractor technical performance.

Many programs do not have the time, technical talent, and budget allocation necessary to perform or oversee these tasks. Some are able to obtain help on a limited basis from "matrix support" engineers. For example, engineers from the US Army Missile Command are supporting the Theater High Altitude Air Defense (THAAD) system program office. However, the current level of overall support falls short of that required.

DoD must act to overcome the design conservatism that is likely to prevail in the absence of appropriate performance and reliability information. The following projects to collect and distribute better data would help:

- Define the environments in which ICs will perform.
- Characterize commercial product performance under various environmental conditions and in actual fielded use.
- Coordinate IC characterization projects and dissemination of results.

Define the Environments in which ICs Perform

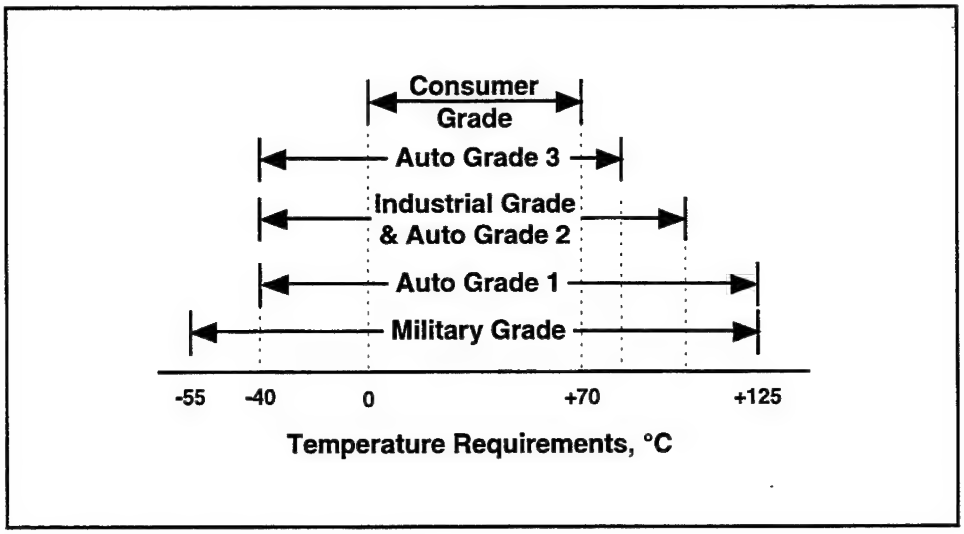
DoD now permits IC specifications to be matched to their operating environment, and Mil-Specs exist defining operating environments for various systems.[1] In practice, however, DoD generally distinguishes between only two operating environments: space and non-space.[2] The military non-space environment is defined so broadly that it includes several commercial environments. Hence, defense equipment designed to the non-space level but used in a benign environment — even in wartime — may be too conservatively designed.

1 See military specifications MIL-E-4158, *General Requirements for Electronic Equipment, Ground* and MIL-E-5400, *General Specification for Electronic Equipment, Airborne* for system environmental descriptions.

2 The space and non-space environments for ICs are implicitly defined by the tests which Mil-Spec ICs are required to pass. Those tests are described in MIL-STD-883, *Test Methods and Procedures for Microelectronic Devices.*

Figure 2-1 illustrates the greater refinement of commercial temperature specifications. The ambient temperature which all defense ICs historically have been required to survive is -55C to +125C. The automotive industry, in contrast, defines three levels of temperature requirements within that temperature range. The most stringent level approximates the traditional military requirement. The consumer electronics industry uses a single, less robust temperature range.

Figure 2-1. The Military Non-Space Environment is Broadly Defined



Sources: MIL-I-38535, CDF-AEC-Q100

DoD should expand the definition of operating environments beyond space and non-space. The non-space environment should be divided into categories that include commercial grades of ICs, such as automotive and consumer. The space environment should be divided based on the radiation resistance required by the system. MIL-HDBK-179A,

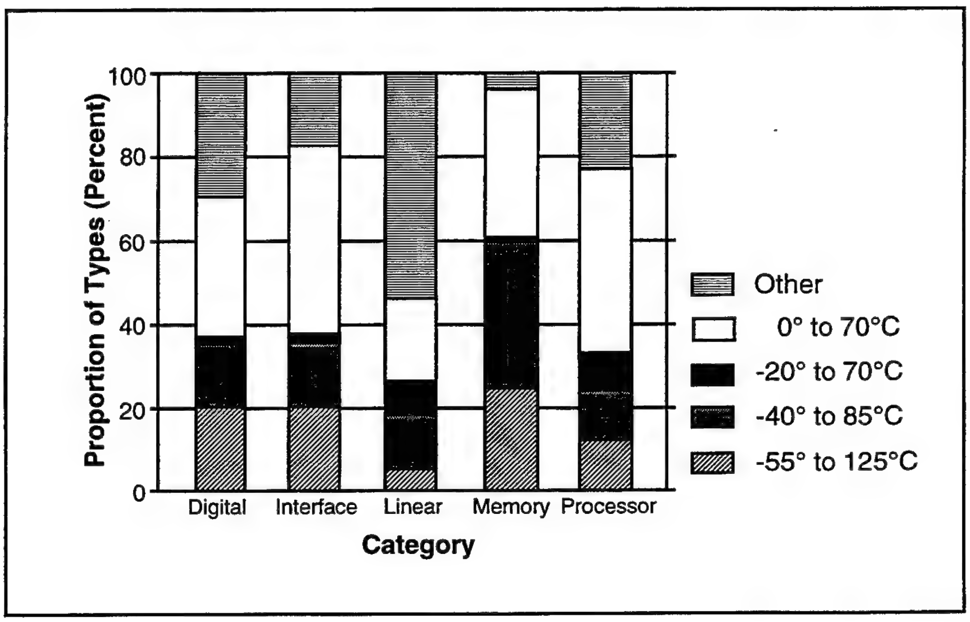
Table 2-1. MIL-HDBK-179A Lays the Groundwork for Expanding Military Operating Environment Definitions Beyond Space and Non-Space

Category	*Typical Applications*	*Typical Operating Conditions*	*Commercial IC Grade Mapping*
Protected	[Office]	0° to +70°C	Consumer Grade
Normal	Ground radar, Aircraft cockpit	-40° to +85°C	Industrial Grade and Auto Grade 2
Severe	Uninhabited aircraft area, Tactical missile	-55° to+125°C	
Space	Strategic missile	-55° to+125°C	

Microcircuit Application Handbook, lays the groundwork for these data distinctions by identifying four types of military operating conditions, shown in Table 2-1. MIL-STD-883, *Test Methods and Procedures for Microelectronic Devices*, should be modified to define environmental grades and tests. The definitions should reference commercial standards corresponding to the operating conditions defined in MIL-HDBK-179A.

Greater refinement in the temperature specification of defense systems would increase the variety of usable commercial ICs. A commercial database containing information about over 316,000 current and discontinued IC products (both military and commercial parts) was analyzed to determine the availability of ICs in the different temperature ranges.[3] Figure 3-2 shows the result of a random sampling of the database, organized into five broad IC categories. Note that in the case of Digital, Interface, and Memory chips, at least 20% of commercial part types are available in the traditional military temperature range. Adding in the -40° to +85° industrial range brings the total to around a third or more in most cases.

Figure 2-2. Availability of Parts Types by Category and Temperature Range



Analysis of the database also shows that, while more ICs are specified in commercial ranges than the traditional military range, these commercial parts tend to have shorter lifetimes. Of the 316,000 parts, only 42.9% of the parts in commercial temperature ranges are listed as "Active,"

[3] Information Handling Services, IC/Discrete Parameter Database, 1994.

compared to 81.7% of the military-range parts. The database lists 23.5% of commercial parts as "Discontinued," compared to only 7.7% of the military parts. It lists the remaining parts in the "contact manufacturer" state, which means their availability is uncertain. This analysis illustrates the need for new defense system design and support strategies, so that the advantage of greater commercial IC availability is not diminished by greater long-term support costs.

Characterize Commercial Product Performance

DoD also needs detailed product specifications. The design specifications published in commercial catalogs are typically aimed at the target market for which the manufacturer's design and production process have been optimized. These published specifications do not necessarily represent the ultimate capability of the product.[4] For example, an IC manufacturer might qualify a consumer-grade device for an automotive application but not make the qualification data readily available. Defense industry engineers contacted by this study indicated that component suppliers seldom provide adequate information to deal with the problems posed by defense environmental requirements.

Table 2-2 lists some of the R&D projects DoD is currently conducting to better characterize commercial ICs and to match them to defense applications.

Table 2-2. DoD R&D Projects Related to Commercial ICs

Project	*Sponsor*
• Reliability Without Hermeticity	Air Force Wright Laboratories
• Physics of Failure • Reliability Audit of Plastic-Encapsulated Microcircuits (PEMs) in Fielded Non-Developmental Item (NDI) Systems	Army Research Laboratory (ARL)
• Microprocessor Technology Utilization Program	Army Missile Command
• Plastic Package Availability Program	Defense Logistics Agency (tri-Service)
• Standard Hardware Acquisition and Reliability Program	Naval Surface Warfare Center
• Dormant PEM Field Reliability Study	ARL and Computer-Aided Life-Cycle Engineering Electronic Packaging Research Center (CALCE/EPRC)

4 Neither military requirements nor product specifications are necessarily fixed. For a given IC design or product, a given percentage will survive outside certain specification limits. Chip-level requirements can sometimes be relaxed (for a price) by making design changes at higher levels of integration (e.g., adding heat sinks or cooling). Similarly, many chips fail probabalistically, rather than catastrophically, when their environmental specification limits are exceeded.

It is difficult to compile a complete list of projects because the projects are small, and while each project is managed by a military department or defense agency, there is no central coordinator. A weapons program office or contractor wishing to learn of research results in areas relevant to their application area must individually contact a multitude of programs, providing they can be identified.

The problem faced by programs and contractors goes beyond mere information-gathering. A simple consolidation of ad-hoc test results or a catalog of commercial parts that have been used in defense applications, while appealing on the surface, would be unproductive, if not misleading. Part information beyond that provided by the commercial supplier is often too narrowly drawn to be directly applicable to another program. One company felt so strongly about the dangers of careless transfer of experimental results that they would not even assemble a list of commercial parts successfully used in one department for use in another department of the same company.[5]

Coordinate IC Characterization Projects and Dissemination of Results

To overcome these problems, DoD should establish a Center for Commercial IC Insertion (CCII) or designate an existing DoD center of expertise to serve in this role. The CCII would help coordinate technical information gathering by serving as a focal point for the variety of DoD entities involved in IC characterization. It would also provide training information and materials. The charter for the CCII would include the following:

- Encourage coordination of IC characterization projects.
- Act as a clearinghouse for IC characterization results.
- Help program offices develop IC requirements and review bidders' specifications.
- Help defense contractors determine when commercial ICs can be used with confidence.

Several alternatives are available for organizing the CCII. The CCII could be operated internally, for example by a Service laboratory or through an Information Analysis Center at the Defense Technology Information Center. This would facilitate up-front securing of funding and technical support to program offices. Such an arrangement would only require a small central staff and could draw on existing Service engineers in their current billets. Another option is to award operation of the CCII to a private research institution specializing in electronics. This option has the benefit of more effective results dissemination and potentially greater

[5] Other programs have found value in the data available for certain devices and applications that has been generated by large IC users. For instance, Honeywell provided analysis of IC field reliability for the Plastic Parts Availability Program (see Section 3).

objectivity. The optimal organization would likely be a hybrid that draws on the strengths of the public and private sector. A hybrid CCII could be organized as a partnership between a Government management office and a technical-support contractor.

A well-managed CCII would help DoD make the best use of its funds for IC characterization. The CCII would encourage coordination between the related projects and provide the means for making the results generally available. This would help program offices and defense contractors determine when commercial ICs can be used with confidence.

Implement Mil-Spec Reform Carefully

The Mil-Spec system largely relieved program managers and contractors of insuring the environmental robustness and reliability of ICs. It also provided essential technical standards that were key to systems integration and helped ensure that replacement parts procured years after initial production would continue to meet the functional requirements of the system. Appendix A presents an overview of the Mil-Spec system and of Mil-Spec reform efforts.

Poorly implemented, Mil-Spec reform can not only eliminate onerous and obsolete Mil-Specs, but also inadvertently eliminate Mil-Specs which are beneficial to defense procurement. Mil-Specs often serve to define and coordinate activities that are essential parts of the contractual relationship between the DoD and industry for which there are no commercial analogs that cover the range of products that DoD buys. Many Mil-Spec standards have gained widespread acceptance in industry, as they establish a common baseline from which to measure performance. Employing a poorly conceived performance specification or unsuitable commercial standard in these cases could lead to inadequate quality and system reliability.

DoD must continue to specify its requirements so that the resulting product will perform its mission with acceptable quality and reliability, and yet encourage the adoption of available commercial technologies. In most cases of concern to the IC industry, alternative specification methods have already identified that remove unnecessary or obsolete requirements embedded in Mil-Specs. These alternatives will help lower purchase cost and permit contractors to use innovative design techniques and advanced technology in areas where commercial advances exceed those of the military. Two recently published government documents — MIL-HDBK-179A, *Microcircuit Acquisition Handbook*, and *Reliability Toolkit: Commercial Practices Edition* (Reference) — provide guidance on appropriate design practices using commercial parts.

In launching the Mil-Spec reform initiative,[6] Secretary of Defense William Perry desired swift action but also stated that this reform should not disrupt programs underway. He permitted Component Acquisition Executives to waive the reform for six months, and stated, "It is not my intent to disrupt on-going solicitations or contract negotiations." However, implementation of Mil-Spec reform by the Services, in addition to being swift and pervasive, was frequently overzealous at first. Initially the Services, especially the Army, banned almost all Mil-Specs from use in contracts regardless of the function of the Mil-Spec, the criticality of the system being procured, or the system's stage in the development cycle. Rather than assessing inclusion of Mil-Specs on their merits, some programs measured success by simply measuring how few Mil-Specs were placed on contract.

Fortunately, these early missteps have been overtaken by more careful consideration of alternatives. The Office of the Secretary of Defense has commissioned a team to review the most onerous Mil-Specs. The team is conducting a rational review that includes looking for commercial alternatives. The Army, Navy and Air Force have granted Service-wide waivers permitting the use of certain Mil-Specs in contracts. Coordination through the Defense Standards Improvement Council has reduced the variation in how Mil-Spec reform is being implemented by the Services. Detailed findings appear in Appendix B.[7]

DoD must continue to move carefully in implementing Mil-Spec reform. The contention that Mil-Specs should simply be eliminated is based on the belief that regulations are the sole root cause of DoD's acquisition problems, and consequently, that reform can solve these problems. There are other causes for the high costs of weapon systems. Many of DoD's regulations and standards are tools to keep those causes under control. It would be unwise to simply abandon all DoD-wide controls and dismantle support organizations.

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6 "Specifications and Standards — A New Way of Doing Business," Department of Defense memorandum from the Secretary of Defense to the Secretaries of the Military Departments, et al., June 29, 1994.

7 Readers interested in more detailed recommendations concerning specific Mil-Specs are encouraged to refer to Gentsch, Peterson & Webster, *Government-Imposed Barriers to the Use of Commercial Integrated Circuits in Military Systems* (Logistics Management Institute report #EC402MR1, February 1996).

Section 3: Overcoming Barriers in Requirements Definition Practices

Most Mil-Spec ICs contain silicon die (bare chips) that are identical to those sold commercially, or are custom-made using commercial processes. Mil-Spec and commercial ICs generally have differed in two ways:

- ❑ The methods and materials used to package the IC die vary.
- ❑ The quality assurance practices applied in manufacturing are different.

In recent years, many defense products have used commercial ICs successfully. Major defense equipment and subsystem suppliers strongly support greater use of commercial ICs. With the contraction of the defense IC supplier base, a wide variety of Mil-Spec ICs is no longer available. Many ICs are available only as commercial products. Wherever feasible, defense programs should be encouraged to eliminate historical Mil-Spec requirements for packaging and quality assurance.

However, DoD must continue to specify its requirements so that the resulting product will perform its mission with acceptable quality and reliability. To further leverage commercial capabilities and to broaden the availability of commercial products that meet defense needs, DoD should reconcile Mil-Specs with best commercial practices in packaging and quality assurance. DoD can accomplish this largely through existing programs, if they are applied with care so as not to raise barriers to the use of commercial IC technology. Specifically, DoD should take the following actions:

- ❑ To better reconcile defense requirements with best commercial practices in packaging, the following efforts are recommended:
  - Establish the capabilities and limitations of commercial packaging technologies.
  - Leverage commercial advances in packaging, especially in areas such as multi-chip modules.
  - Continue R&D investments in advanced packaging materials and computer design tools.
- ❑ To better reconcile defense requirements with best commercial practices in quality assurance, the following efforts are recommended:
  - Create commercial interest in the Qualified Manufacturers List (QML) program by providing technology transfer in related areas of DoD expertise.
  - Enhance Standard Microcircuit Drawings (SMDs) to capture IC specifications in a form compatible with commercial standards.

Note: In certain technology areas, defense needs differ from commercial needs and cannot be met through packaging and quality assurance. Commercial ICs generally cannot operate reliably in the radiation environment following a nuclear explosion. Some DoD applications require ICs with classified designs, which must be manufactured in specially cleared facilities and protected with technologies that prevent reverse engineering. In certain defense applications, distinct benefits are achievable from devices that are more advanced than mainstream commercial applications of the same devices. For example, distinct defense benefits are achievable in radar and electronic warfare applications from high-performance analog ICs. Custom, application-specific ICs can be essential in defense applications in which minimization of size and weight are paramount concerns.

Continue Efforts to Meet Military Requirements using Best Commercial Practices in IC Packaging[1]

IC packaging, commonly referred to as first-level packaging,[2] is the science and art of establishing interconnections and a suitable operating environment for microcircuits. The typical IC package provides connections to and from the silicon chip, a means of removing generated heat, and protection from moisture, radiation, temperature, and mechanical vibration and shock. IC packages are typically made out of plastic, ceramic, or metal. Today, 95% of Mil-Spec ICs are packaged in hermetically sealed, ceramic IC packages.[3] However, because the materials and assembly process for plastic packaging are significantly less expensive in high-volume production than that for ceramic or metal packaging, about 97% of commercial ICs are packaged in plastic.[4]

The ceramic-versus-plastic distinction has been a focal point in debate about DoD electronics policy. Major military merchant vendors support increased use of commercial plastic-encapsulated microcircuits (PEMs) in defense systems.[5] Several defense products already employ PEMs,

1 *Semiconductor Packaging: A DoD Dual Use Assessment,* Department of Defense, April 1995, provides a comprehensive treatment of packaging issues and is the basis for most of this section.

2 Second-level packaging is the attachment of the substrate onto the circuit card, and third-level packaging is the attachment of the circuit card into higher levels of the system.

3 Though most Mil-Spec ICs are in ceramic packages, Mil Spec ICs do not comprise the majority of the ceramic market. The majority of ceramic packaged ICs are commercial ICs. Many high-performance, state-of-the-art, commercial microprocessors use ceramic packaging.

4 Michael Pecht, Rakesh Agarwal, and Dan Quearry, "Plastic Packaged Microcircuits: Quality, Reliability and Cost Issues," *IEEE Transactions on Reliability*, (Vol. 42, No. 4, December 1993), pg. 516.

5 Minutes of the Application and Operating Environment Workshop and Summary of the Support and Design Techniques Workshop, The Multi-Use Manufacturing Work Panel of the Industry Task force for Affordability and The Institute for Defense Analyses, June 9-10, 1994. Summary Report and Recommendations for Accelerating the Use of Commercial Integrated Circuits in Military Systems, The Multi-Use Manufacturing Work Panel of the Industry Task force for Affordability, August 1995.

including: Mobile Subscriber Equipment, Precision Lightweight Global Positioning System (GPS) Receiver, SINCGARS radios, the AN/FPS 124 radar, the AN/ARC 164 airborne radio, and sonobuoys.[6] In other cases, programs have been more reluctant to move away from the proven reliability of ceramic packages. The reluctance is greater when ICs must perform under extreme temperature and humidity conditions, or when ensured operation after long-term storage is important.[7]

The results of various scientific experiments comparing the reliability of plastic versus ceramic packaging have not resolved the fundamental dispute. A major effort under the Plastic Package Availability (PPA) Program investigated several different ceramic and PEM technologies and manufacturing processes under various harsh operating conditions. It found higher failure rates for PEMs compared to ceramic packages in most experiments. [8] Other studies have shown higher failure rates for ceramic ICs.[9] Many studies have found that failure rates for all types of ICs can vary widely among suppliers.[10]

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[6] Briefing charts supplied by Mr. Edward Hakim on December 7, 1994. Mr. Hakim is the Chief, Component Reliability Branch, Electronics and Power Sources Directorate, US Army Research Laboratory, Ft. Monmouth, New Jersey.

[7] *Proceedings of the Case Studies Symposium on the Successful Use of Commercial Integrated Circuits (IC) in Military Systems, Vol. II*, Sponsored by the Industry Task Force on Affordability, Alexandria, VA, June 13-15, 1994. For information on potential reliability degradation during long-term storage, see Noel Donlin, "A Study of the Use of Plastic Encapsulated Microcircuits Versus Hermetically Sealed Microcircuits for Meeting Missile System Mission Critical Reliability Requirements," US Army Missile Command Technical Report RD-QA-94-1, (June 1994), and Noel Donlin,"The Reliability of Plastic Encapsulated Microcircuits and Hermetically Sealed Microcircuits in MICOM Missile Systems," (February 1995).

[8] The Defense Electronic Supply Center sponsored the PPA program. Each Service and NASA provided management participation. National Semiconductor served as the prime contractor, and Rome Laboratory performed test and failure analysis. Work on the PPA program started in late 1992 but was delayed until mid-1994 due to a lapse in Government funding.

[9] Pecht, et al. *Plastic Packaged ICs.* A study done by Rockwell-Collins compared plastic mounted devices against ceramic packaged devices in a 3532 hour temperature cycling test. The parts were cycled every 4 hours between -40° and +85° C in 85% relative humidity with 5 v. dc bias -- a test designed to simulate a worst-case avionics environment. The failure rate for plastic devices was 1.6% per 10^6 hours. The failure rate for ceramics was 6.1% per 10^6 device hours.

[10] Papers on this subject include: Brizoux, M. et al., "Plastic Encapsulated ICs in Military Equipment Reliability Prediction Modeling," *Quality and Reliability Engineering International*, vol. 8 (1992) pp. 195-211; Condra, L. and Pecht, M., "Commercial Microcircuit Options in Military Avionics Systems Demand Reliability," *Defense Electronics* (August 1991) pp. 43-47; Condra, L., O'Rear, S. Freedman, T., Flancia, L., Pecht, M., and Barker, D., "Comparison of Plastic and Hermetic Microcircuits Under Temperature-Humidity Bias," *IEEE Trans. Comp. Hybrids Manufacturing Tech*nology, 15,5 (October 1992), 640-650; Crook, D. L., "Evolution of VLSI Reliability Engineering," *Proc. 1990 International Reliability Physics Symposium,* (March 1990) pp. 2-11; and Watson, G. F., "Plastic-Packaged ICs in Military Equipment," *IEEE Spectrum* (Feb. 1991).

The actual field reliability experience of a major systems manufacturer (and PPA participant) indicated superior reliability for many types of PEMs. Likewise, all of the respondants to a survey of more than 60 military equipment and subsystem suppliers indicated that commercial ICs were equivalent or superior to Mil-Spec ICs in terms of performance, cost, reliability, size, weight, and availability.[11]

Establish the Capabilities and Limitations of Packaging Technologies

Given the central importance of the packaging issue, DoD should continue efforts to establish the capabilities and limitations of commercial packaging technologies. Additional work should include the following efforts:

- Develop the "Highly Accelerated Stress Testing" qualification method.
- Characterize near- and long-term packaging failure modes.
- Develop reliability data on long-term storage of electronics.
- Improve the scientific methods for evaluating new packaging materials and structures, especially the physics-of-failure approach to determining root causes of semiconductor packaging failures.

DoD should leverage ongoing work at Department of Energy defense laboratories, the National Institute of Standards and Technology (NIST), and universities to help develop understanding in these areas.

Leverage Commercial Advances in Packaging

DoD should also continue research aimed at leveraging commercial advances in packaging, especially for new, higher density designs. For example, single-chip surface mount, multi-chip module (MCM), and direct chip attach (chip on board) designs can yield substantial gains in system performance, reliability, and compactness.[12] High-performance MCMs offer particular promise. An MCM contains several individual ICs mounted together within a single enclosure. High-performance MCMs can be hermetically sealed. Hence, they offer an attractive way to insert commercial ICs into defense systems that must operate in harsh environments.

DoD R&D and manufacturing technology investments in high-performance MCMs should reduce the cost barriers to their commercial adoption. The cost barriers are associated with making a wide variety of tested, unpackaged ICs, or "known good die," available. The Defense Advanced Research Projects Agency's Electronic Packaging Program is addressing the cost barriers.

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[11] Memo to the Unndersecretary of Defense for Acquisition and Technology from the Chief of the Display Science and Reliability Branch of the US Army Research Laboratory, Fort Monmouth, June 17, 1996.

[12] As with plastic packages, it will be necessary to develop a thorough knowledge of the technical trade-offs. There will continue to be certain defense applications in which investment in non-commercial technology can provide military advantages.

Continue R&D Investments in Packaging Materials and Design Tools

DoD should continue investments in technology areas that increase the availability of commercial ICs that meet defense needs. Two high-payoff areas that have already been identified and funded — advanced packaging materials and computer design tools — should be continued. Advanced packaging materials with good thermal dissipation can provide for higher IC operating temperatures. Computer-aided design tools that include more complete capabilities for thermal, mechanical and electrical analysis can help predict potential packaging failures in advance. Projects should be cost-shared with industry where possible. This will encourage commercial adoption of the resulting capabilities.

Continue Moving Toward Use of Best Commercial Practices in Quality Assurance

Present methods for manufacturing Mil-Spec ICs were established in the 1960s and 1970s. During this period, IC manufacturing was still more of an art than a science. The Mil-Spec quality control methods that emerged relied heavily on testing and screening of finished components. Since then, manufacturers have drawn on years of experience and failure studies of thousands of devices to increase continually their ability to build in quality and reliability through control of design, testing, and manufacturing processes. This body of engineering knowledge, coupled with statistical process control methods, has yielded dramatic improvements in the reliability of ICs. Now many IC characteristics can be guaranteed by design. Today microelectronic devices are rarely the cause of electronic equipment failures in commercial applications.[13]

The trend is toward attaining quality and reliability by design rather than by a testing process. However, not all IC characteristics can be guaranteed by design. Some DoD requirements warrant testing. An industry group advocating the military use of commercial ICs noted that special testing of commercial ICs could be required before insertion into all but benign, controlled operating environments.[14] Table 3-1 summarizes their findings, using the operating environments defined in MIL-HDBK-179A, listed in Table 2-1.

[13]Michael Pecht and Vijay Ramappan, "Are Components Still the Major Problem: A Review of Electronic System and Device Field Failure Rates," *IEEE Transactions on Components, Hybrids, and Manufacturing Technology*, (Vol. 15, No. 6, December 1992), pp. 1160-1164.

[14]The Multi-Use Manufacturing Work Panel of The Industry Task Force For Affordability and The Institute for Defense Analyses, Accelerating the Use of Commercial Integrated Circuits in Military Systems, Interim Report, September 1994, p. 10.

Table 3-1. Potential Special Testing Needs Depend on the IC Operating Environment

Operating Environment	*Potential Need for Special Testing of Commercial ICs*
Protected	No
Normal	Yes
Severe	Yes
Space	Essential

Commercial quality assurance standards and environmental test specifications are typically set on a company-by-company basis and can vary widely.[15] Commercial users of ICs such as the automobile industry maintain stringent quality control standards and testing requirements, and they audit their IC suppliers to ensure compliance. As DoD moves toward greater use of commercial ICs, program offices and contractors will need to know their suppliers and stay up-to-date on the state-of-the-art in IC manufacturing. Two government programs — the Qualified Manufacturer's List (QML) and the Standard Microcircuit Drawing (SMD) Programs — can facilitate the transition in defense electronics acquisition toward use of best commercial practices.

The QML Program Can Help Increase the Number of Defense Suppliers

The QML program was implemented in 1989 after numerous recommendations by industry and defense review panels.[16] Prior to QML, individual ICs needed to be tested and qualified for military use. Under QML, DoD assesses an IC *manufacturer's* ability to design and produce parts that consistently meet DoD performance specifications and to maintain consistent quality as they improve their processes. The QML lists suppliers passing the audit.

QML has been helpful in reducing the economic incentives for traditional defense IC suppliers to curtail their support of the defense market. QML permits suppliers to adopt best commercial practices in their IC manufacturing process and to combine commercial production with

[15] Some industry standards are emerging. In 1994, the automotive industry issued CDF-AEC-A100, *Quality System Assessment for Semiconductor Suppliers* and CDF-AEC-Q100, *Stress Test Qualification for Automotive-Grade Integrated Circuits.* The Joint Electron Device Engineering Council (JEDEC) of the Electronic Industries Association (EIA) has issued an analogous standard for consumer-grade ICs (JEDEC Standard #47). The JEDEC device configuration and environmental test specifications are widely used commercially, are referenced in MIL-STD-883, *Test Methods and Procedures for Microelectronic Devices,* and are listed in the *EIA, JEDEC, and TIA Standards and Engineering Publications* catalog.

[16] The QML program is defined by the military performance specification, MIL-PRF-38535, *Integrated Circuits (Microcircuits) Manufacturing, General Specification for.* It extensively references MIL-STD-883, *Test Methods and Procedures for Microelectronic Devices.*

defense production. The QML also eases former military restrictions on offshore production.

DoD should continue adapting QML to changes in commercial practices, as this provides a path for defense IC suppliers to become more commercially competitive.[17] Commercial suppliers who do not derive significant revenue from DoD business have little incentive to consent to QML audits or to bear the financial cost of certification. So individual defense programs must be free to employ equivalent commercial quality standards, where they exist, along with innovative parts control and documentation strategies. Mandatory use of QML suppliers would be a barrier to use of commercial ICs.

DoD can create commercial interest in QML by providing IC technology transfer to commercial companies in related areas of DoD expertise such as design and manufacturing processes that enhance high-temperature IC operation, radiation resistance, and mechanical ruggedness. Commercial companies must perceive participation in QML as a means of acquiring technical expertise that can provide entry into new commercial applications for their ICs as well as expanding their opportunities to supply DoD.

The SMD Program Can Support Future Defense IC Acquisition

An SMD is a technical specification that defines the performance characteristics and quality assurance provisions for an individual IC or family of IC devices, regardless of the manufacturer.[18] Manufacturers and DoD use technical specifications to procure ICs and to track hardware configuration over time. It is not uncommon for commercial IC manufacturers to change product specifications without assigning a new part number or notifying customers. A cornerstone of the SMD program is the manufacturer's agreement to notify the Defense Logistics Agency (DLA) of changes. DLA then keeps the SMD current.

The SMD relieves the IC user, typically a defense Original Equipment Manufacturer (OEM), of the obligation to develop and maintain specifications for each IC it uses. With the SMD program, a defense-wide specification for a given product is developed only once, rather than by each OEM using the device (at DoD expense). The elimination of duplication simplifies DoD's inventory management system and helps

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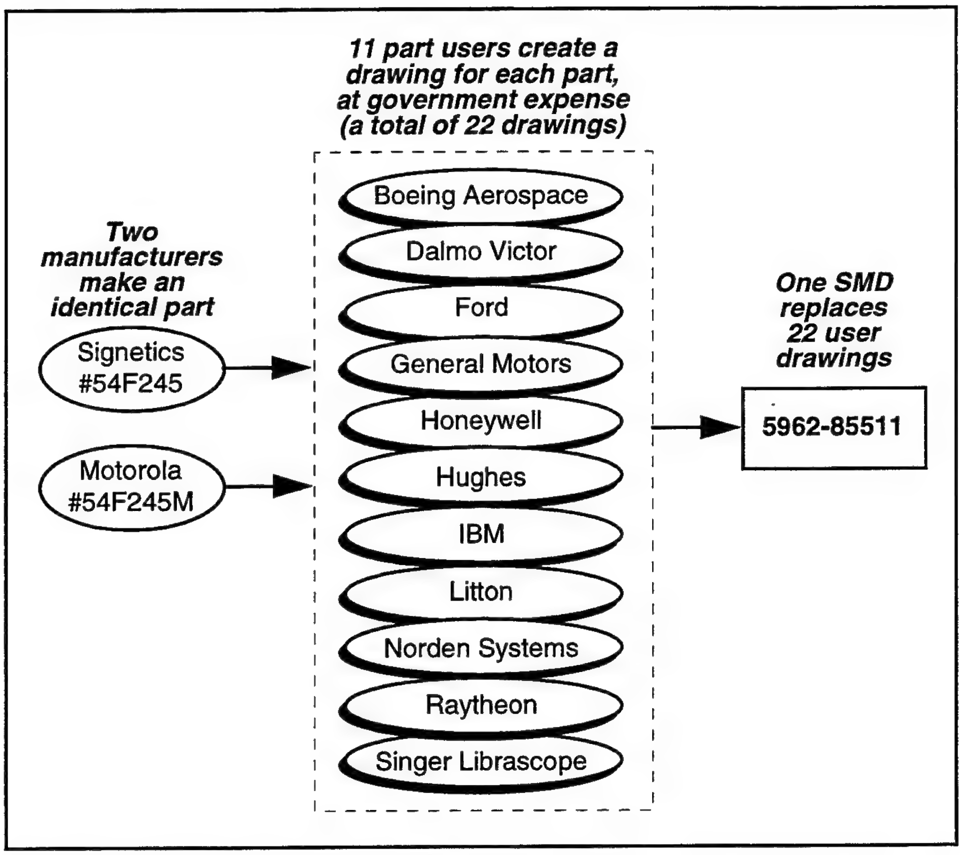
[17] Readers interested in more detailed recommendations concerning QML are encouraged to refer to Gentsch, Peterson & Webster, *Government-Imposed Barriers to the Use of Commercial Integrated Circuits in Military Systems* (Logistics Management Institute report #EC402MR1, February 1996).

[18] SMDs are managed by the Defense Logistics Agency (DLA). MIL-HDBK-780, *Standardized Microcircuit Drawings* defines the format for SMDs. MIL-BUL-103, *List of Standard Microcircuit Drawings*, is a catalog of SMDs with a cross reference to generic part numbers where they exist.

avoid both excess inventory and supply disruptions. Figure 3-1 illustrates how the SMD program prevents proliferation of part numbers.

To support a future defense acquisition strategy that is more compatible with best commercial practices (see Section 1), SMDs need to be enhanced. Capturing IC specifications in a computerized hardware description language (HDL) would provide a better interface to commercial companies. Using an HDL to specify complex ICs could also allow reordering from other than the original manufacturer.

Figure 3-1. SMDs Reduce Proliferation of Part Numbers



Source: Interview with Mr. Mike Frye, DESC, October 12, 1994.

Section 4: Overcoming Barriers in Contracting Practices

The Federal Acquisition and Streamlining Act of 1994 (FASA), the Federal Acquisition Reform Act of 1996 (FARA), and their regulatory implementation have made major improvements in government contracting for commercial items. In the interim, historical cultural barriers may remain pending education of the defense acquisition workforce and changes in the procurement practices of prime defense contractors. In the case of the IC industry, it is critical that DoD work to clarify the changes made in government auditing rights and intellectual property ownership in the acquisition of commercial items and for government-funded work.

In the longer term, DoD should continue exploring innovative contracting procedures that are consistent with commercial practices, facilitate competition, and encourage life-cycle cost and performance trade-offs. A wider cultural change is called for, one that rewards program managers for prudent risk-taking and managerial innovation.

Introduction

Historical US government business practices inhibited commercial IC suppliers from participating in DoD markets. Clauses included in government contracts — and flowed down to lower tier subcontractors — often called for practices, procedures or agreements that differed significantly from commercial norms. These clauses subjected suppliers to oversight and liabilities that they did not face in their commercial dealings.

FASA and FARA[1] have eliminated most of the unique laws and regulations that discourage commercial IC firms from doing business with DoD. The implementation of FASA and FARA promises to remove the statutory and regulatory requirements that followed from these legal barriers. Traditional barriers fall into the following general categories:

- Cost or pricing data.
- Cost collection and reporting requirements.
- Source restrictions.
- IC design data rights.
- Precious and specialty metals restrictions.

[1] See Appendix A for background on FASA and FARA.

The remainder of this section describes the significant strides acquisition streamlining efforts have made in removing these types of barriers. It highlights important factors for the IC industry that must be addressed as FASA and FARA are implemented.[2]

Cost or Pricing Data

Commercial IC firms have frequently identified cost or pricing data contract clauses as barriers to doing business with the government. These clauses required a contractor or subcontractor to disclose detailed accounting and financial information in the proposal and to provide government and higher-tier contractor personnel access to related records. The purpose of these regulations was to ensure that the price paid by DoD was reasonable. Commercial firms typically are not asked to and do not, as a matter of policy, disclose such sensitive financial information to commercial customers.

To make matters worse, there were also potential civil and criminal sanctions associated with incomplete or incorrect disclosure to the government. For example, if an error or mistake is misconstrued as defective data, the government could apply criminal and civil penalties. Criminalization of the procurement process forced firms that sold in both government and commercial marketplaces to separate their operations and record keeping into government and commercial units. This separation protected their commercial technologies and financial records and limits potential liabilities to organizational units set up and staffed to comply with DoD's unique requirements.

FASA addressed and significantly revised government accounting practices. It established new methods for contracting officers to establish price reasonableness, with detailed cost or pricing data last in order of preference. Audit rights were significantly revised, but remained as a potential barrier. Section 4201 of FARA resolved this and other remaining problems by providing a blanket exemption from cost and pricing data requirements and related audit requirements for the acquisition of a commercial item. Implementation of FARA into the Federal Acquisition Regulation is in process.

Cost Collection and Reporting Requirements

Cost collection and reporting practices threw up additional barriers to commercial firms. For certain major systems programs, DoD required a special type of cost and progress reporting known as Cost/Schedule Control Systems Criteria (C/SCSC).

[2] The "Military Products from Commercial Lines Pilot Program" is an example of the elimination of administrative barriers by FASA and FARA. Under this program, circuit boards for the F-22 and RAH-66 Comanche will be produced on a commercial manufacturing line that produces automotive components. The circuit boards have been certified as commercial items, thereby providing the full relief provided for by FARA and FASA for acquisition of commercial items.

The rewrite of DoD Regulations[3] specifically relieved requirements for contractor cost data reporting for commercial systems. In addition, implementation of Title VIII of FASA into the Defense Federal Acquisition Supplement eliminated cost and schedule control systems requirements in DoD contracts and subcontracts for commercial items or components.[4]

Source Restrictions

The US Government has historically restricted the use of foreign-made products in defense items. For instance, the Buy American Act favors domestic products by requiring a cost differential to be added to foreign product offers. Other contact clauses required a prime contractor to list any components that were not of domestic manufacture and to certify that the item offered meets the domestic content requirement.[5] Source restrictions such as these have no counterpart in the commercial world and could cut off DoD from a wide range of suppliers — including overseas plants of U.S. corporations (which is common in the integrated circuit industry).

While source restrictions were not addressed by FASA at the prime contract level, implementation of FASA into the Federal Acquisition Regulation precluded flowing these restrictions down to subcontractors providing commercial items or commercial components. FARA promises further relief from these restrictions for prime contracts for the acquisition of commercially available off-the-shelf items. For instance, FARA provides authority to extend the use of simplified procedures for the acquisition of commercial items up to $5 million. Proposed implementation of Section 4203 of FARA includes the Buy American Act on the list of statutes that should no longer apply to such acquisitions.[6] DoD is further considering adopting a single rule of origin, consistent with the Trade Agreements Act.[7]

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[3] DoD Regulation 5000.2-R — Mandatory Procedures for Major Defense Acquisition Programs (MDAPs) and Major Automated Information Systems (MAIS) Acquisition Programs.

[4] Department of Defense, *Defense Acquisition Circular* 91-9, November 30, 1995.

[5] To qualify as a domestic end product, a product must be mined or produced in the United States, and more than half of the cost of its components must originate in the United States. Trade agreements to which the United States is a partner exclude ICs excluded from the list of goods and services covered.

[6] *The Federal Register* on May 13, 1996.

[7] William J. Perry, Secretary of Defense, *Annual Report to the President and the Congress*, March 1996, p. 115. "Rules of origin" are laws, regulations and administrative determinations included in trade agreements to define the country of origin of goods. Origin questions have become increasingly complex as a result of the "multinationalization" of certain industries, where the producer may source its components from different countries, or may manufacture the product in successive stages in different countries. The manufacture of ICs and electronic systems are increasingly multinational in both respects.

IC Design Data Rights

Both the government and the contractor have legitimate interests in the technical data used or delivered under a government contract. DoD needs certain system component data to operate, repair, test, and support the equipment. This includes data to train personnel, and to ensure replacement parts are available at competitive prices during the equipment's life. The contractor may have concerns about disclosing design or manufacturing information to potential competitors. Such disclosure can compromise the contractor's competitive position, given the central and essential role of intellectual property rights in the growth, success, and survival of high technology commercial firms.

Consider a contractor that has developed, at their own expense, new design techniques or fabrication processes. They could be reluctant to apply such new technologies to a component that, at least initially, will be unique to a government system or program. If they do apply the new technology in a government program and deliver the technical data to the government, their competitors may gain access to the technology.

Government and industry have struggled for decades to find the best way to accommodate their needs and interests. Approaches have ranged from government insistence on unlimited rights, to virtual reliance on sole source suppliers. Neither extreme has succeeded in satisfying the parties.

One of the significant advances made in the FASA is a presumption that the commercial item technical data is developed at private expense and therefore ownership of the technical data remains with the company. In addition, implementation of Title VIII of FASA into the DFARS eliminated the inclusion of government unique data rights clauses in subcontracts for commercial items or components.[8] Prime contractors may not require subcontractors or suppliers at any tier to relinquish data rights as a condition for award of any contract, subcontract or purchase order. Further, as a result of implementation of Section 8003 of FASA, the statutes governing DoD's unique technical data rights requirements were made inapplicable to subcontracts for commercial items or components.[9] DoD policy is to acquire only the technical data customarily provided to the public with a commercial item or process, even if the commercial product is embedded in a military-unique item.[10] If a defense program requires data rights beyond those provided commercially, access to the data must be negotiated, not imposed.

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[8] Department of Defense, *Defense Acquisition Circular* 91-9, November 30, 1995.

[9] 10 U.S.C. 2320, 10 U.S.C. 2321.

[10] Department of Defense, *Defense Acquisition Circular 91-8*, 30 June 1995.

Despite the changes brought about by FASA and DoD policies, past understandings of the government's approach to the allocation of intellectual property rights may continue to hold force among firms that have historically not done much government business. In 1984, Congress enacted the Semiconductor Chip Protection Act (17 USC 901, et seq.). This act defined "mask works,"[11] an entirely new class of intellectual property distinct from either patents or copyrights. No policy guidance exists to address how government contracts should handle mask works. This lack of guidance will not necessarily affect suppliers of truly commercial ICs. However, it can have a potentially devastating impact in situations where a supplier would design a custom chip for a defense program and then seek to introduce it into the commercial marketplace. If the mask work is treated like any other design, the government owns the rights. Consequently, the government could give the design away and thereby hurt the firm's position in the marketplace. To the extent that the custom design utilizes proprietary design or process techniques, the supplier may face compromise of critical competitive advantages. Therefore, DoD should draft implementing regulations for the Semiconductor Chip Protection Act. These regulations should acknowledge different rights for an IC design and permit the designing firm to retain commercial application rights.

Precious and Specialty Metals Restrictions

Both precious and specialty metals are used in the manufacture of ICs. According to the U.S. Census of Manufactures, material inputs to the semiconductor industry include gold and other precious metals, and the specialty metals alloy steel, stainless steel, and nickel alloys. The Defense Industrial Supply Center (DISC) has traditionally managed the use of precious and specialty metals in defense systems. If a contracting officer identified a requirement for precious metals, and if they are available from DISC, he/she inserted the "Intent to Furnish Precious Metals as Government-Furnished Material" clause into the solicitation. The contractor then had to submit two prices — one including the cost of contractor-furnished metals and one based on the use of government-furnished metals. The contracting officer evaluated the cost of the Government-furnished metal and made the award on the basis of best interest to the Government.

Implementation of FASA provided relief from these requirements by precluding the "Intent to Furnish Precious Metals as Government-Furnished Material" clause in any contract or subcontract for the

[11] Mask works are a transparent (glass or quartz) plates covered with an array of patterns used in making integrated circuits. Each pattern consists of opaque and transparent areas that define the size and shape of all circuit and device elements.

acquisition of a commercial item or component.[12] It also exempts subcontracts for commercial items from the "Preference for Domestic Specialty Metals" clause, which implements Section 9005 of the Department of Defense Appropriations Act of 1993 (Public Law 102-396), known as "the Berry Amendment."

12 Department of Defense, *Defense Acquisition Circular* 91-9, November 30, 1995.

Appendix A: Background

Historical Perspective

DoD develops distinct military technical requirements to meet the following general requirements:

- Ensure the reliability of systems that are exposed to harsh environments or stored for long periods.
- Maintain performance for years or decades in life-critical systems.
- Obtain long-term engineering and logistics support.

When DoD was a dominant customer in the IC industry, these requirements were documented in Mil-Specs. IC suppliers developed separate government production and marketing organizations to meet these technical requirements and the associated government-unique administrative requirements.

The growth of commercial IC demand and concomitant competitive pressures caused the industry to focus less on the DoD market. The DoD acquisition process was unable to keep pace with increasingly rapid commercial product development cycles. By the 1980s, defense technology in fielded systems had fallen years behind the commercial leading edge.

DoD was the Dominant Customer of the IC Industry

Because of the military implications of microelectronics, DoD and other federal agencies have had significant interest in the development of the US microelectronics industry since its inception. An Air Force program on molecular electronics has been credited for stimulating the thinking that led to the invention of integrated circuits in 1958 by Jack Kilby, Texas Instruments, Inc. Through the early 1970s, roughly half of the funding for semiconductor research and development (R&D) came from DoD. Perhaps of greater importance than R&D support was the commitment in the 1960s to use of ICs in the Minuteman II and Apollo Programs. The early creation of a government market underwrote the development of large scale production capability and led to the unchallenged technological superiority and global market domination that the US held through the 1970s.

Mil-Specs Communicated Requirements

The practices by which DoD acquired ICs changed as the semiconductor industry expanded. DoD and the National Air and Space Administration (NASA) were driving the market in the early 1960s, and government program managers and their defense contractors worked in close coordination to develop special-purpose products. As manufacturing capabilities grew and prices dropped, ICs became viable commercially and affordable for a wider variety of defense applications. To facilitate coordination among a now much larger group of suppliers and defense customers, DoD developed Mil-Specs for environmental robustness, reliability, quality, parts configuration control, and logistics support. The Mil-Spec system permitted designers of defense systems to select standard

parts out of company catalogues. The designer had confidence that the parts would operate reliably in harsh military environments or after long-term storage, and that they would be supported for years or decades of use. In many cases, Mil-Specs became commercial industry standards.

Mil-Specs generally evolved as manufacturing technology improved, allowing DoD to take advantage of commercial market efficiencies and product improvements. The silicon die (bare chips) for most Mil-Spec parts were, and still are, manufactured in the same manner as standard commercial parts and then specially packaged and tested. Still, prior to current DoD reform efforts, changes in modern manufacturing practices made many Mil-Specs obsolete.

Government Business Practices Differed from Commercial Practices

US Government purchasing, auditing, and logistics practices also differentiated DoD from commercial customers. Clauses included in government contracts often called for practices, procedures, and agreements that differ from commercial norms. Under a government contract, suppliers were subjected to oversight and liabilities that they did not face in their commercial dealings.

IC Suppliers Separated Commercial and Government Divisions

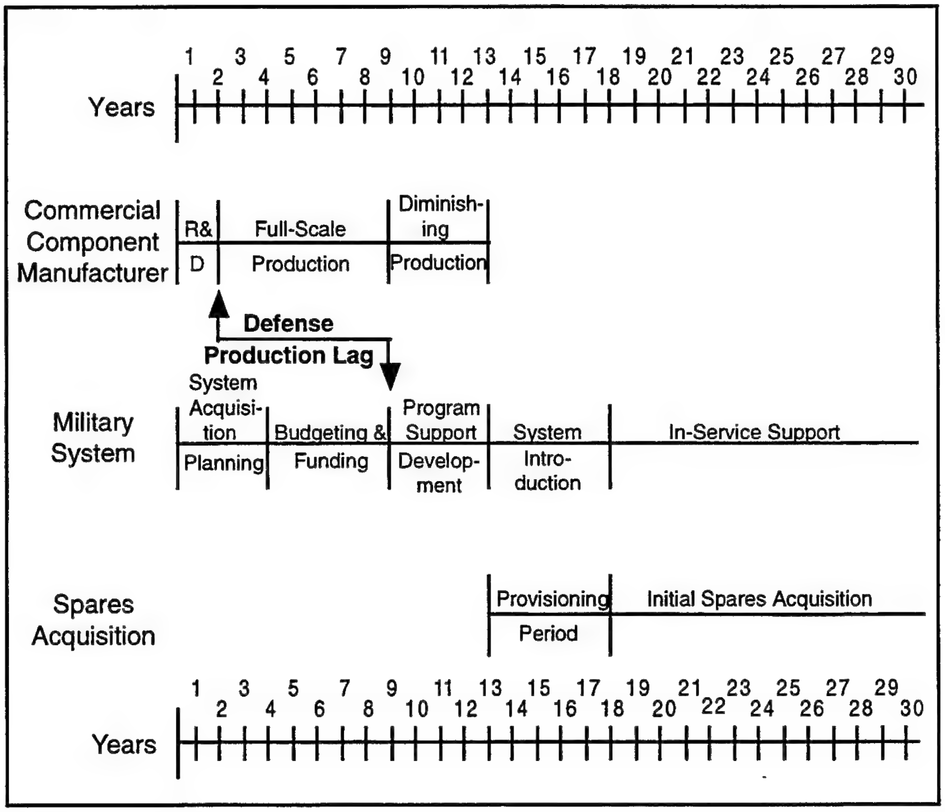
As a result of the technical and administrative differences, companies found it necessary to build separate production facilities and marketing organizations to serve defense customers. Organizational units were set up and staffed to comply with DoD's unique requirements. Companies made this separation in order to protect their commercial technologies and financial records and to contain potential liabilities. IC firms that sold in both defense and commercial marketplaces also tended to maintain separate defense and commercial operations and record keeping.

Economic Pressures Changed the IC Industry

Competitive pressures in the IC industry drove product development cycles down to about a year, and new generations began to be introduced every three or four years. In the DoD acquisition process, it typically takes ten or more years to develop or upgrade new systems.

Figure A-1 compares a typical life cycle for a weapons system with that of a relatively long-lived commercial IC. Weapons system requirements and design decisions are presently made on the basis of the performance of components that either already exist and can be used in prototypes, or that can reasonably be expected to exist within a few years. The risk inherent in the latter strategy increases as the number of years forward that one attempts to predict gets larger. Long delays between system design and production means that parts in fielded systems may not only be technologically obsolete (superseded by improved versions) but may not even be generally available by the time the first production units of the weapons system are introduced into the field. Moreover, the long expected life of the weapons system, and the general practice of maintaining electronics by replacement at the component level, results in a demand for parts long after normal production has ceased.

Figure A-1. Comparison of Commercial and Defense Product Life Cycles



In this environment, defense technology in fielded systems grew increasingly distant from the commercial leading edge. By the 1980s, Mil-Spec parts were typically being introduced years after functionally equivalent commercial offerings.

DoD and the Current IC Market

At present, DoD largely finds itself in a reactive mode. Some programs are attempting to develop new system design practices and electronics support strategies to take advantage of what has become available commercially. Other programs are scrambling to cope with the loss of suppliers for specific military parts and technologies. DoD is taking steps to encourage companies to continue serving the defense market. But keeping the Mil-Spec supplier base is becoming increasingly difficult for two related reasons:

- DoD demand is a very small and decreasing proportion of the total IC market.
- The rising cost of state-of-the-art manufacturing facilities is making low-volume production uneconomical.

The volume of commercial production has grown to the point where defense IC consumption is essentially invisible to the major IC suppliers.[1] Worldwide merchant IC sales were over $90 billion in 1994 and growing at an average rate of over 20% per year.[2] In contrast, merchant sales of Mil-Spec ICs[3] totaled only $1.1 billion in 1994, just 1.3% of the worldwide market, and have been relatively flat for a number of years (See Figure A-2). Hence, major suppliers have had a strong incentive to focus their resources on larger, more profitable commercial markets where products may be sold without cumbersome contracting procedures and commitments to long-term product support. While some traditional defense suppliers remain committed to serving the DoD market with the best technology achievable affordably at low volumes, other major IC producers have already dismantled their military sales and manufacturing operations.[4]

Not only is defense demand for ICs small in relation to global production, but its market profile also differs significantly from commercial demand. Commercial buyers tend to purchase high volumes of a small number of chip device types, while DoD buys a low volume of thousands of different device types. One major semiconductor producer, for example, has 150 part numbers for the automotive market and 12,000 part numbers for the defense market.[5] Also, DoD tends to purchase older parts that are near or beyond the end of their commercial life cycle. Commercial IC product development cycles are down to about a year, with prices driven down as volumes increase, while electronics designs for major DoD systems are typically frozen several years before production begins. DoD design and support practices make it difficult to take advantage of newer technology at lower prices. In some cases this forces DoD to pay more for the old technology than it would for newer, more capable technology. As a result,

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1 There are some exceptions: for certain low-volume ICs such as specialty analog parts and devices fabricated on materials other than common silicon, defense consumption is greater than commercial consumption.

2 "Merchant sales" refer to direct sales of ICs on the open market, which accounts for most of the market. The figures do not include "captive sales," that is, ICs produced by systems manufacturers for use in their own products, which totaled approximately $6 billion in 1994.

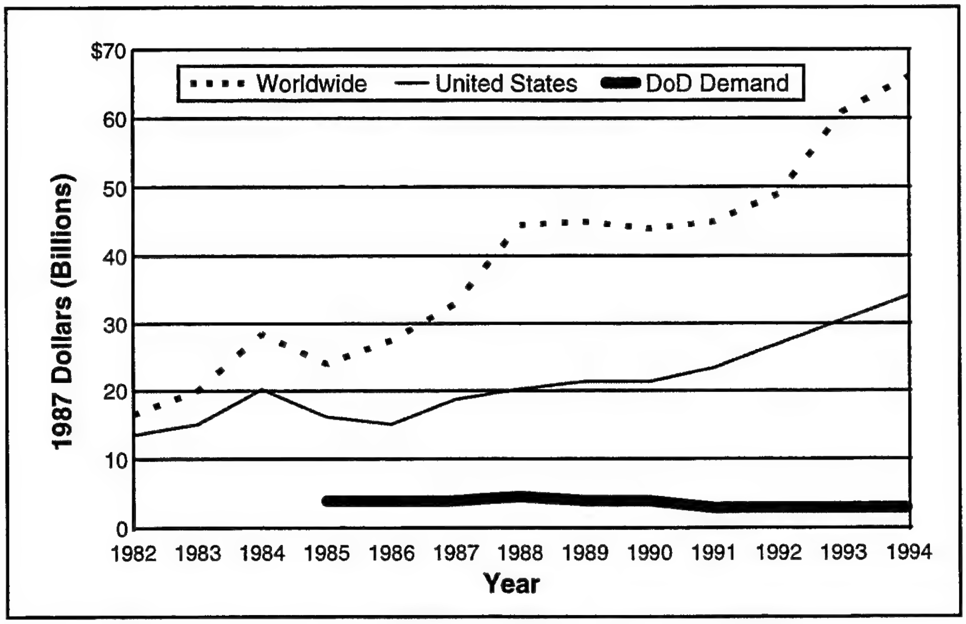
3 Mil Spec parts are defined as those manufactured under MIL-M-38510/QPL or MIL-I-38535 QML/SMD, or that meet the testing requirements of MIL-STD-883.

4 In 1994, Motorola and AMD announced plans to eliminate separate organizations to supply the military. DoD will remain a customer of interest but will no longer be served by separate production and sales organizations.

5 Department of Defense, DoD Microcircuit Planning Group, *Commercialization Status Report and Progress Report on Implementing the Defense Science Board Recommendations [on] Microelectronics,* October 1993.

defense systems often incorporate out-dated IC technology that must be supported for the many years or decades that the systems are operational.

Figure A-2. DoD IC Consumption is a Small Part of the Total Market



Sources: US Industrial Outlook, for US shipments and 1993-1994 world shipments; Semiconductor Industry Association, for 1982-1992 world shipments; Defense Economic Impact Modeling System (DEIMS), for DoD demand.

The increased complexity of modern ICs is pushing the cost of state-of-the-art fabrication facilities to over a billion dollars. Mitsubishi reported spending $1.6 billion for construction of a wafer fabrication plant in 1993. Intel plans construction of a $1.8 billion plant in 1996. To understand how complexity drives manufacturing cost, consider the example of Dynamic Random Access Memories (DRAMs). Moving from the 65,536 bit DRAMs produced in 1980 to the 1 Gigabyte DRAM expected by 1998 will mean increasing the number of manufacturing process steps from 150 to as many as 700. The total capital cost for a 1 Gigabyte DRAM fabrication plant capable of 20,000 wafer starts per month will be about $2 billion, compared to $150 million for the 1980 DRAM Facility.

The fixed capital cost of such a facility can only be amortized affordably over hundreds of millions or even billions of parts. Under today's production technology, very low-volume runs are largely precluded in such facilities. Hence, without a change in the basic manufacturing philosophy for ICs, state-of-the-art factories dedicated to Mil-Spec production cannot remain economically viable.

Increased IC complexity is also making extensive, end-of-the-line Mil-Spec testing more costly and time-consuming. It is already impossible in some cases to validate IC operation under every possible set of inputs. Furthermore, quality control in modern manufacturing facilities has improved to the point where much of this end-of-the-line testing is unnecessary. Certain high-quality, high-reliability applications still demand extensive testing and burn-in, but in many instances defense users can have greater confidence in the quality of ICs by using a standard part. Standard parts, produced in millions, using statistical process controls, can have better quality than a part produced in batches of only a few thousand and then heavily (but partially) tested at the end-of-the-line. These users would also benefit from having access to the best technology sooner.

The "Global Threat of Technology"

The need to employ advanced commercial IC technologies in US defense systems is part of a broader imperative in the current national security environment. For the past 50 years America's national security threat was primarily defined by the global nuclear and conventional capability of the former Soviet Union. The collapse of Communism and end of the Cold War profoundly changed the way national security needs are defined. Today the US faces challenges that are different but no less complex: the spread of nuclear weapons and other weapons of mass destruction; major regional, ethnic, and religious conflicts; uncertainty about democratic reform in the former Warsaw Pact and the developing world; and potential challenges to the economic viability of industrial capabilities vital to our national security.

Coincident with these new challenges, the US faces a new type of threat: an emerging global technology threat. The US no longer dominates many of the technologies used in the military. Technology diffusion permits potential adversaries rapidly to improve their military systems. Several intelligence reports point to increasing use by other countries of readily available, commercial off-the-shelf (COTS) technologies.[6] For instance, commercial ICs are available worldwide. More than half of the world's IC manufacturing capability and technical expertise in related technologies now resides overseas. The US cannot deny other countries access to these technologies. Potential adversaries can and will employ advanced commercial ICs in their defense systems.

[6] Lt. Charles D. Ormsby, NAIC/TATA and Mr. Robert L. Robke, NAIC/GTU, *Use of Commercial-Off-The-Shelf Equipment in Military Systems -- Worldwide*, 3 July 1995 (Secret); Dennis K. Evans and Daniel W. Barr, DIA, *Microelectronics in the Pacific Rim Countries*, Document #DST-1700S-665-94, April 1994 (Secret); L. Dunn, D. Dwyer, D. Louscher, and J. Tomashoff, *Diffusion of Military Technology and Its Implications for US Defense Policy*, SAIC report # 079-04-295-0002AD, September 1990 (FOUO).

The DoD must prepare for this emerging technology threat. The threat is different than the traditional view of a threat from a specific country. The diffusion of dual use technology makes it difficult to predict when, where and how threats may emerge and how the US may be involved. Countering the technology threat and preserving future US advantage will depend on inserting advanced technologies into fielded systems more rapidly than potential adversaries.

DoD leadership advocates the merging of the commercial and defense supplier bases as the primary way to achieve more rapid insertion of advanced commercial IC technology. Secretary of Defense Perry's *Acquisition Reform: A Mandate for Change* of February 24, 1994, states:

> Commercial technology advancements are outpacing DoD-sponsored efforts in the same sectors that are key underlying technologies for military superiority. DoD must have unimpeded access to commercial technologies more quickly than other countries if it is to maintain its technological superiority... [In order to] maintain its technological superiority in today's environment, [DoD must] be able to rapidly acquire commercial and other state-of-the-art products and technology, from reliable suppliers who utilize the latest manufacturing and management techniques. DoD must integrate, broaden, and maintain a national industrial base sustained primarily by commercial demand but capable of meeting DoD's needs.

This mandate was followed in February 1995 by *Dual Use Technology: A Defense Strategy for Affordable, Leading-Edge Technology*. This strategy statement, in addition to promoting the insertion of commercial technologies into defense systems, called for the following actions:

- ❑ Invest in research and development (R&D) on dual use technologies to ensure the domestic commercial technology base remains at the leading edge in areas critical to the US military.
- ❑ Transfer defense production technologies into commercial industry to leverage commercial economies of scale and scope.

Federal Acquisition Reform

To reduce costs and ensure that defense technologies and systems keep pace with rapid advances in the commercial sector, DoD has begun to remove technical and administrative barriers imposed by the government itself. Reform efforts seek to eliminate unique, government-imposed contracting, technical, and accounting requirements. The goal is a simplified, commercial-style procurement system that gives priority to acquiring commercial products and processes.

Two reform efforts are leading toward removal of barriers and accomplishment of the goals envisioned by the Dual Use Strategy: Military Standard and Specification (Mil-Spec) reform, and the acquisition streamlining.

Military Specifications and Standards

In order to understand the benefits and limitations of the changes that are being made to the DoD acquisition system relevant to ICs, it is helpful to have an overview of the Mil-Spec system.

Military standards establish uniform criteria, methods, processes and practices for developing military unique applications. Military specifications document requirements for development of military unique hardware. While commonly associated with the military specification, the term Mil-Spec also refers to the following documents:

- Military standards,
- Military handbooks,
- Military bulletins,
- DoD standards,
- NATO standards, and
- Any other document listed in the DoD Index of Standards and Specifications (DoDISS) and maintained by the DoD or other military agency.

Approximately 40,000 Mil-Specs provide:

- Procedures for consistent system development and engineering, e.g. for design reviews and configuration control,
- Product specifications,
- Test and calibration methods, and
- Other technical references.

Mil-Specs include both technical standards and management standards. Technical standards and specifications are designs and manufacturing processes that are accepted by an industry or imposed by a buyer on its suppliers. Use of standard designs and parts can lead to savings in several ways:

- Standardized designs are off-the-shelf and the performance of parts made from the designs is known.
- Configuration standards are maintained by a third party, usually at no direct cost to either the manufacturer or the customer.
- There is little production risk with established, acceptable production methods.
- Competitive sources are available or can be developed for replacement parts.

Management standards cover accounting methods and cost reporting, engineering management, and program reporting. The standards allow both current and long-term comparisons of program data across Services and also reduce the training necessary for government managers, accountants, and engineers.

Impact of Mil-Spec Reform on IC Procurement Process Flow

Secretary of Defense Perry set forth a dramatic vision for simplification of the way the Pentagon buys defense systems in *Acquisition Reform: A Mandate for Change*. As part of the mandate, on June 29, 1994 the Secretary issued a memorandum titled *Specifications and Standards—a New Way of Doing Business.* Mil-Specs define technical requirements for military parts and systems. These technical requirements and the associated government-unique administrative requirements can be barriers to commercial firms doing business with DoD. The *Specifications and Standards—a New Way of Doing Business* memorandum directs the military Services to "use performance and commercial specifications and standards instead of military specifications and standards, unless no practical alternative exists to meet the user's needs." This represents a complete change of DoD practice. Rather than being required, Mil-Specs are only to be used as a last resort. (Appendix B summarizes the study efforts leading to the June 29 memorandum. It also describes the efforts and status of Mil-Spec reform at the Office of the Secretary of Defense (OSD) level and for each of the Services.)

Figures A-3 and A-4 describe the general process flow and Mil-Specs pertaining to IC selection, design, and manufacture for military use. The Mil-Specs listed are those that existed in 1994 when the Perry memorandum was issued. Dashed borders and italicized type indicate the impact of Mil-Spec reform. The numbered sections below describe the contents of the corresponding boxes in Figure A-3 and Figure A-4.

1. Determine Device Requirements

The figure illustrates that Mil-Specs can serve many different purposes. Contractual system performance requirements lead to IC device requirements. Device requirements include not only functionality but also the operating environment and support issues.

2. Military Part Required, or Free to Use Commercial Part?

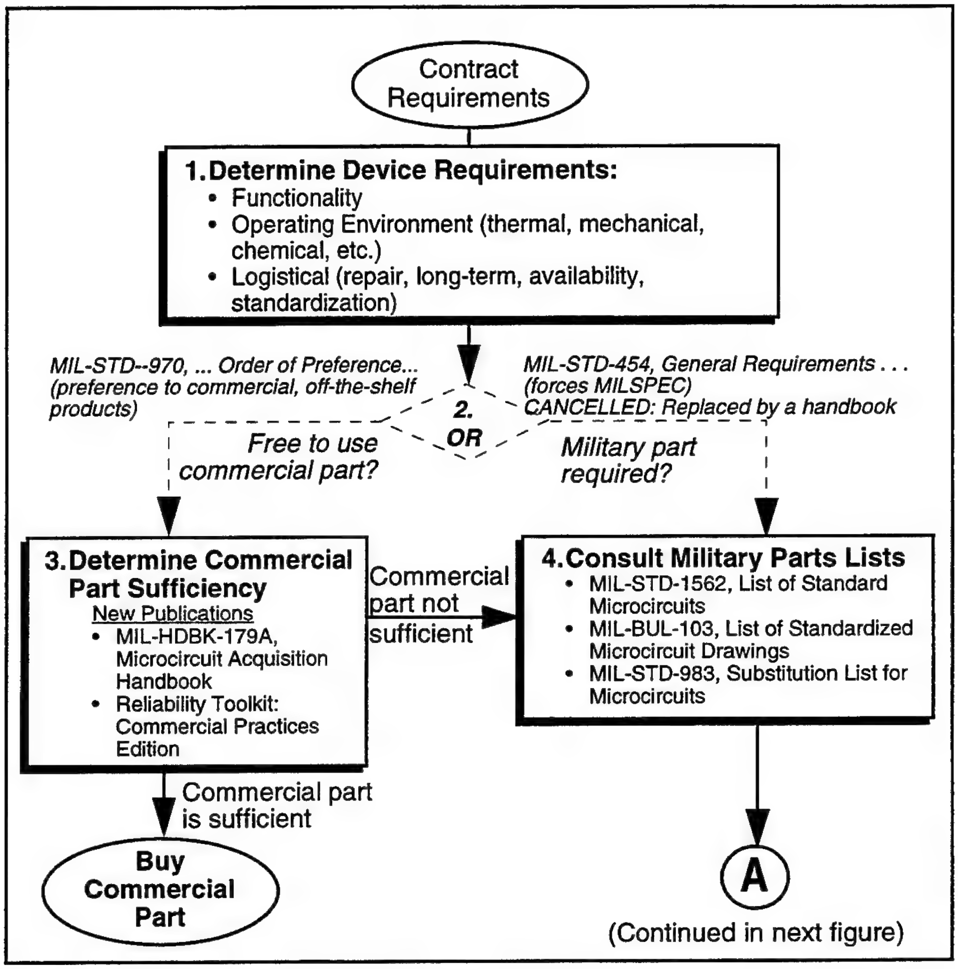
In the past, if a contract included MIL-STD-454, *Standard General Requirements for Electronic Equipment*, Requirement 64 of that standard dictated that military ICs must be used. Under Mil-Spec reform, MIL-STD-454 was replaced by a Military Handbook. MIL-STD-970, *Specifications and Standards, Order of Preference for*, was canceled. MIL-STD-970 was used to permit contractors to choose commercial parts.

3. Determine Commercial Part Sufficiency

Commercial ICs are still frequently eliminated from consideration because insufficient data exists supporting their ability to meet the IC device requirements for the application. In 1995, two new references -- MIL-HDBK-179A, *Microcircuit Acquisition Handbook*, and *The Reliability*

Toolkit: Commercial Practices Edition[7] -- were published to help evaluate commercial parts. If the commercial part does suffice, the contractor may buy it.

Figure A-3. IC Procurement Steps Before and After Mil-Spec Reform (1994) (Part 1)



4. Consult Military Parts Lists

An engineer using a military part had to first consult a military parts list. This was done to control the proliferation of parts in the supply system and the attendant inventory costs. The lists available include the following:

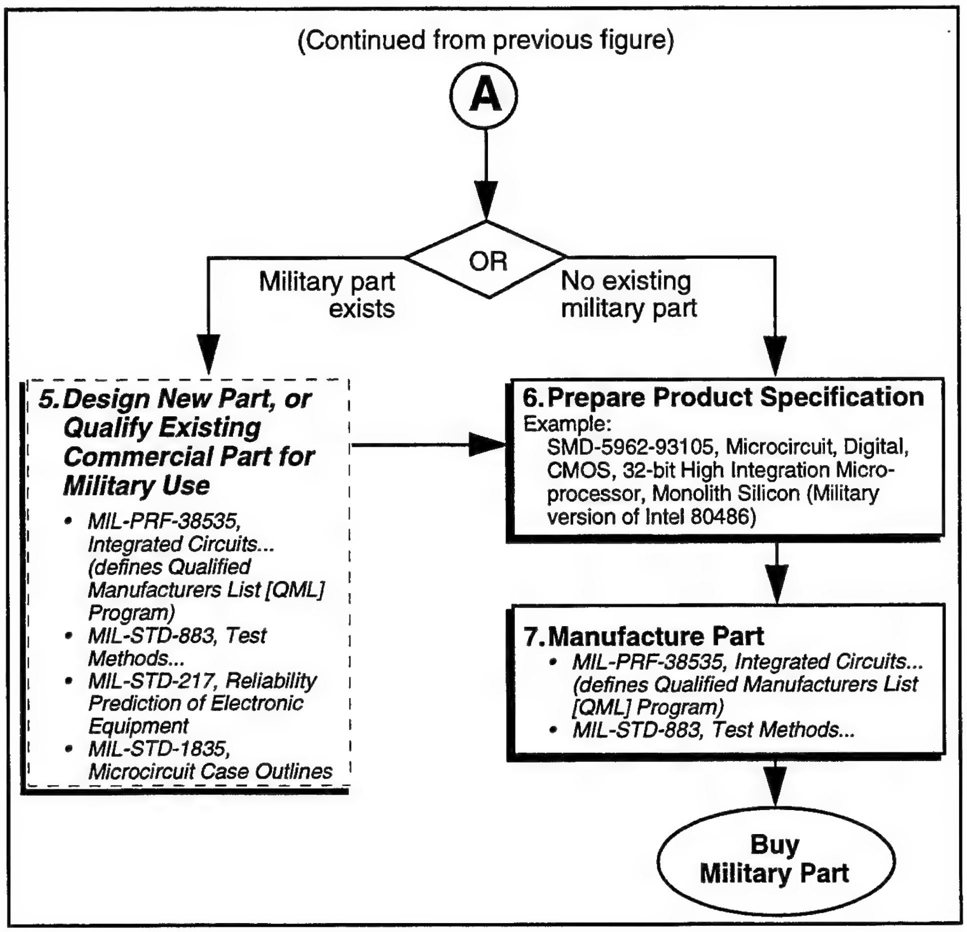
- ❑ MIL-STD-1562, *List of Standard Microcircuits*, lists older parts qualified for military use.

[7] Published by the Reliability Analysis Center at Rome Laboratory.

- MIL-BUL-103, *List of Standardized Microcircuit Drawings*, lists newer parts approved for military use, including militarized versions of commercial ICs.
- MIL-STD-983, *Substitution List for Microcircuits*, provides a cross-reference between military and commercial or generic part numbers.

The rest of the IC procurement process flow is shown in Figure A-4.

Figure A-4. IC Procurement Steps Before and After Mil-Spec Reform (1994) (Part 2)



5. Design New Part, or Qualify Existing Commercial Part for Military Use

If a military part does not exist to do the job, the contractor must design a new device or qualify an existing commercial device for military use. A number of Mil-Specs can apply explicitly and implicitly to that activity, if they are called out in the contract:

- MIL-PRF-38535, *Integrated Circuits (Microcircuits) Manufacturing, General Specification for,* outlines quality assurance provisions and defines the Qualified Manufacturers List (QML).[8]
- MIL-STD-883, *Test Methods and Procedures for Microelectronic Devices*, implicitly determines many IC performance requirements by prescribing the electrical, thermal, mechanical, and chemical tests that devices must pass.
- MIL-HDBK-217, *Reliability Prediction of Electronic Equipment,* provides mathematical models for reliability prediction. (The methodology embodied in this handbook is now considered incorrect. The Army has made reference to this document unacceptable in any new Request-for-Proposal or contract.)
- MIL-STD-1835, *Microcircuit Case Outlines,* defines standard form and fit (electrical lead configurations) for connecting ICs into circuit boards.

6. Prepare Product Specification

When a new military part is designed, or a commercial part is qualified for military use, a product specification called a Standard Microcircuit Drawing (SMD) is prepared. SMDs are usually prepared by the IC manufacturer, but can also be prepared by the IC user or by the Government. Since commercial IC manufacturers can change product specifications at will and without notice, the SMD provides a baseline or stable product definition.

7. Manufacture Part

During product manufacture, two main Mil-Specs can apply: MIL-PRF-38535, *Integrated Circuits (Microcircuits) Manufacturing, General Specification for* and MIL-STD-883, *Test Methods and Procedures for Microelectronic Devices*. Note that these Mil-Specs influence both the design and production of ICs. Also, contrary to popular perception, Mil-Specs do not prescribe manufacturing methods for ICs. There is debate over the necessity of end-of-the-line testing required by the IC Mil-Specs, but many have been eliminated under MIL-PRF-38535.

FASA Addresses Administrative Barriers

On October 13, 1994, the President signed the Federal Acquisition Streamlining Act of 1994 (FASA, Public Law 103-355). This law was intended, among other purposes, to make it easier for the government to acquire goods and services from the commercial marketplace. FASA

[8] MIL-PRF-38535 is a "performance specification" that superseded the former Mil-Spec MIL-I-38535. MIL-PRF-38534 applies for hybrid ICs.

made a wide range of changes in acquisition policy and procurement law. The major changes include the following:

- The definition of what qualifies as a commercial product is expanded.
- Purchases of commercial items are exempted from over 30 statutes unique to the government.
- Contracts for commercial items are exempted from the requirement to provide cost and pricing data.
- The threshold under the Truth in Negotiations Act is raised to $500,000.
- The simplified acquisition threshold is raised to $50,000 and will go up to $100,000 when certain conditions are met. Purchases made under that threshold are exempted from 15 statutes.
- More extensive debriefings are required upon award of contract to reduce the number of protests.

FARA Expands on FASA

The Federal Acquisition Reform Act of 1996 made additional legal changes to increase government use of commercial products and processes. These additions simplified government purchases of commercial items in several ways:

- They give a contracting officer flexibility in determining the reasonableness of the price of the contract, subcontract, or modification.
- They authorize the use of simplified acquisition procedures for the acquisition of commercial items valued at $5 million or less, when the contracting officer reasonably expects that responses to such offers will include only commercial items.
- They require the Federal Acquisition Regulation (FAR) to be modified to include a list of procurement provisions that are inapplicable to contracts for the procurement of commercially-available off-the-shelf items.
- They expand the definition of commercial items to include those items for which the price is based upon established market prices sold in substantial quantities to the general public.
- They eliminate certain cost accounting standards.

These legal changes will reduce oversight, simplify contracting procedures, and bring government contracting closer to commercial practices. Regulatory initiatives intended to implement FASA and FARA are in various stages of completion, with some proposed rules already out for public comment, while others are still being developed and coordinated internally.[9]

[9] It should be noted that full FASA implementation will require changes and additions to both the Federal Acquisition Regulation (FAR), which applies to all government purchases, and the Defense Federal Acquisition Regulation Supplement (DFARS), which promulgate additional rules for DoD purchases. In accordance with a plan approved by the Office of Federal Procurement Policy, all implementation efforts are initially focused on the FAR. Necessary or appropriate DFARS implementation language and actions will take place only after all FAR changes are finalized. As of the time of this report, not all of the implementing FAR actions had been either published or finalized.

Appendix B: Implementation of Mil-Spec Reform

While specification reform had been underway for many years with programs like Air Force MIL-Prime, it received new and dramatic impetus in 1994. In April 1994 the results of a process action team (PAT) review of military specifications and standards were published in a report titled "Blueprint for Change." On June 29, 1994, Secretary of Defense Perry signed a memorandum implementing the PAT recommendations and directing specific actions by the Services.

In making these recommendations, little consideration was generally given to the benefits of Mil-Specs and the technical environment of military procurement. The specification reform program has been justified based on Mil-Spec cost alone.[1] A number of program managers and engineers contacted by this assessment expressed concern about the course of Mil-Spec reform. While these people welcomed the opportunity to take advantage of commercial standards and products, they indicated that reform was forcing them to abandon Mil-Specs that assured them of quality or program control, even when a commercial substitute was not available.

The contention that Mil-Specs should simply be eliminated is based on the belief that regulations are the sole root cause of the problems, and consequently, that reform can solve the problems. There are other causes for the high costs of weapon systems, and, in fact, many of the regulations and standards are tools to keep those causes under control.

OSD Implementation of Mil-Spec Reform

The Office of the Secretary of Defense (OSD) Standardization Office has established a team to review all military standards with the goal of replacing them with appropriate industrial standards, reclassifying, or canceling them. This team has assigned the most frequently criticized Mil-Specs to various DoD groups for review. The team's goal is to eliminate all unnecessary military standards, leaving a library of only those standards deemed essential to defense contracting.

OSD has issued a policy on the elimination of Mil-Specs. This policy covers the documents themselves, not their application in Requests for

[1] From March to October 1994, Coopers and Lybrand and TASC conducted a quantitative assessment of the costs of government regulations (including Mil-Specs) for Secretary Perry. This study was not directed to consider the benefits of Mil-Specs. Page 3 of a briefing on the project to Secretary Perry stated: "...some claim that DOD receives substantial benefits from its regulatory activities. The Project Team did not attempt to validate the existence of such benefits or quantify their value. In other words, we looked only at the 'cost' portion of the cost benefit ratio." (*The DoD Regulatory Cost Premium: A Quantitative Assessment,* briefing by Coopers and Lybrand and TASC to the Secretary of Defense, December, 1994).

Proposals (RFPs) and contracts. That application is being governed by the Services and is discussed below. The OSD policy is that military specifications and standards are to be canceled only after a review determines that they are no longer needed. Scores of Mil-Specs which met this condition have been cancelled without replacement. In other cases, they are being replaced by a variety of new constructs[2]:

FOR SPECIFICATIONS

- Performance specifications that describe product performance rather than design detail.
- Specifications using both performance and design detail where it has been determined that some amount of the design detail is essential to achieving a defense-specific capability.

FOR STANDARDS

- Non-government standards (both performance and design) for products, test methods, practices, etc.
- Acquisition guides for management and technical information requested of the contractor during the solicitation process.
- Interface standards that describe essential interface characteristics.
- Data specifications that describe data products to be delivered.
- Test method standards describe testing procedures to ensure uniform, comparable results.
- Manufacturing process standards that state the desired outcome of a manufacturing process.
- Standard practices that describe procedures for services, functions, or operation not related to a manufacturing process.
- Handbooks providing reference information, acceptable practices, terminology, etc.

Service Implementation

When the Perry memo was first released in June of 1994, there were no guidelines for implementing its provisions. Although the Perry memo provided a six month transition period, many acquisitions that were approaching final RFP release were directed to remove all references to Mil-Specs. The first formal guidelines were generated by the Army, but these were not available until November 1994. During this five month period many different approaches were taken to satisfy the requirement of using Mil-Specs only as a last resort in RFPs.

2 Internet site at http://www.acq.osd.mil/es/std/stdans1.html, May 20, 1995.

Inappropriate measures of effectiveness of the reform initiative were employed by the Services during this period, and some continue to be used. The most offensive was the comparison of the number of Mil-Specs referenced in an RFP before "the new way of doing business" with the number after revising the RFP. Programs with no Mil-Specs were touted as successful simply on the basis of a count. Requests for waivers were initially disallowed. Eventually, the need for a waiver process was recognized, but to request a waiver was considered a failure to implement the reform. Fortunately, this attitude is changing and the waiver process is now considered a necessary part of buying reliable military systems. The Navy and the Air Force have granted Service-wide exemptions to specific Mil-Specs and allow these exempted documents to be referenced as requirements without a waiver in acquisitions. Each of the Services has now established standardization reform groups. These groups have the responsibility to respond to the Process Action Team's report and to establish ground rules for use of Mil-Specs in procurements.

The policies on implementation of Mil-Spec reform for the Army, Navy and Air Force are summarized below. It should be noted that while official policy has been issued Service-wide, application at lower levels within each Service may be more stringent than the Service-wide policy.

The Army's Policy

The Army was the first to publish formal guidelines to standardization reform, the "Army Implementation Plan," dated 23 November 1994. The Army policy is to prohibit the use of Mil-Specs in all acquisition programs unless authorized by a waiver granted at the appropriate level as identified by the Army Implementation Plan. The prohibition applies to all acquisition programs, including all acquisition categories (ACATs), rebuys, procurements of services, replenishments and spares. Through the end of fiscal year 1995, the Army had not exempted any Mil-Specs. In the first quarter of fiscal year 1996, the Army exempted 28 Mil-Specs, virtually all related to information technology.

The Navy's Policy

The Navy does not yet have a document that formally addresses implementation of Mil-Spec reform. However, its policy is as follows. If a program is a reprocurement with minimal or no change, the Mil-Specs required in the original procurement may be invoked without a waiver. The goal in any new procurement, or in reprocurements with significant change from the original procurement, is not to require **any** military specifications and standards. If a program is a new procurement, a waiver must be obtained to require specific Mil-Specs in the RFP. The waiver requirement excludes exempted Mil-Specs. If a Mil-Spec has received a Service-wide exemption, it may be invoked without a waiver. At the end of the first quarter of fiscal year 1996, the Navy had exempted 21 standards, including, for example, the following:

- MIL-STD-461, Requirements for the Control of Electromagnetic Interference Emissions Characteristics,
- MIL-STD-462, Measurement of Electromagnetic Interference Characteristics,
- MIL-STD-498, Software Development and Documentation, and
- MIL-STD-1388, DoD Requirements for a Logistics Support Analysis Record.

The Air Force's Policy

The Air Force has an official policy document on the implementation of acquisition reform that is under review at the time of writing. In general, the policy for use of Mil-Specs in procurements is that waivers must be obtained unless the document has received an Air Force exemption. To date, the Air Force has exempted over 40 Mil-Specs. Of the Navy-exempted standards listed above, the Air Force has exempted the first three. It is interesting to note that while the Navy exempted MIL-STD-1388, the Air Force expressly denied this standard an exemption.